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PRINCIPLES AND PRACTICES

OF

CROP PRODUCTION IN INDIA

IN TWO PARTS

PART I

General Principles of Crop Production

BY

C. P. DUTT & B. M. PUGH

PART II

FIELD CROPS

BY

B. M. PUGH & C. P. DUTT

Available from

B. M. PUGH,

Allahabad Agricultural Institute,

Allahabad, U. P., India.

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FOREWORD

In a province such as the United Provinces where the bulk of the population depend for their livelihood upon agriculture and where Government depends for its revenue mainly on the produce of the land, any measure for the improvement of agriculture must be welcomed. Mr. Pugh, Professor of Agronomy in the Allahabad Agricultural Institute and at present officiating Principal, and Mr. C. P. Dutt, who was at one time Professor of Botany, have produced a most useful book entitled "The Principles and Practices of Crop Production in India." This book should prove most helpful not only to students at the Institute but to all agriculturists, to landholders and tenants; to the owners of large farms as well as to the cultivator of a small holding. It will no doubt soon get a wide circulation and I hope it may prove possible to translate portions of it, especially those portions which give practical advice to the cultivator, into the vernacular of the province, so that it may reach a wider circle of readers.

It must be remembered that "whoever can make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, deserves better of mankind and does more essential service to his country than the whole race of politicians put together." The Agricultural Institute and all connected therewith are rendering this essential service to the United Provinces, and in this book the authors show how it is possible to make two ears of corn grow where only one grew before. At this time when many countries of the world are being devastated by war it is the more necessary for all agriculturists to do their utmost to increase the produce of their fields. I commend this book to the notice of all.

MAURICE HALLETT,
K.C.S.I., C.I.E., I.C.S.,
Governor of the United Provinces.

July 17, 1940.

DEDICATED TO

THE AGRICULTURAL SCIENTISTS OF INDIA

BOTH PAST AND PRESENT

PREFACE

Several books on agriculture in India have been written from time to time, but it is felt that the materials contained in them are not sufficient to meet the requirements of students of agricultural colleges in this country and do not cover the work that has been done by agricultural investigators in this country in recent times. The authors have also felt that very much valuable material lies buried in journals and magazines which are not often available to the student or to an educated farmer in this country. This book therefore has been written in order to make the great wealth of material so far published easily available in a concise form. To some the book may appear to be too technical and to others it may appear altogether inadequate for their purpose. For the latter group the numerous references at the end of each chapter are given for more detailed study as well as for further elucidation of certain points that are mentioned in the book. Although the authors have tried to cover all the materials on or relevant to the subject matter taken up in the book, they believe that omissions are possible.

In the course of preparation of this book the authors realized the very great difficulty of writing a book on Indian field crops. The large size of the country, the great variety of climate and the very wide diversity of crops and cultural practices in different parts of the country, make the whole subject a very difficult one to handle.

The book has been divided into two parts: (1) the principles underlying crop production, and (2) the field crops in this country.

In dealing with the cultural practices in the production of crops, the authors have attempted to give the practices generally followed by the cultivators, although these practices may or may not be the best. In the treatment of the subject matter and wherever an opinion has been expressed, the authors take sole responsibility. Any criticisms that readers may wish to make in order to improve the book will be greatly appreciated by the authors.

Acknowledgments are due to the Institute of Plant Industry, Indore, for the facilities made available to the authors in the preparation of this book. The authors also take this opportunity to thank Mr W. B. Hayes, Vice-Principal of the Allahabad Agricultural Institute, and Mr. K. Ramiah, Geneticist and Botanist, Institute of Plant Industry, Indore, C. I., for carefully reading the manuscript and for the suggestions made which have greatly increased the accuracy in many places.

BY THE AUTHORS.

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PRINCIPLES AND PRACTICES

OF

CROP PRODUCTION IN INDIA

PART I

General Principles of Crop Production

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PRINCIPLES AND PRACTICES OF CROP PRODUCTION IN INDIA

CHAPTER I

INTRODUCTION

Beginnings of Agriculture.—Agriculture is a very ancient occupation of mankind. It is so old that nobody can say with certainty when and where it was first begun. It probably began when man through necessity discovered that certain wild plants about him would furnish him food in the form of fruits and seeds. Following this discovery, he probably went from place to place in search of these food materials. Some of the seeds of these food materials probably dropped around his dwellings, and later bore the fruit and grain which he could use again as his food. This again led him to discover that by scattering seeds near his dwelling, he could have his food materials near his home without having to search for them at long distances. The primitive man perhaps also realized that the fruits and seeds gathered were not sufficient to meet his needs and those of his family. This led him to the cultivation of crops so as to supplement the natural supply. He then probably had recourse to the clearing of jungles for the growing of his crops. But he probably found out also that the continuous growing of crops in the same place gives diminished yields. So he probably moved about from place to place. Later as population grew, he was forced to restrict himself to a certain locality. This again must have resulted in competition for certain favourable localities, and the giving up of his nomadic life.

In the course of time this primitive man again must have discovered that certain wild plants which he was growing gave him more and better food than others. This must have led him to the selection of certain wild plants for cultivation. In this way, primitive man made a remarkable choice of crops. Civilization began to centre around the growing of certain crops like wheat in Central Asia, rice in China and South-eastern Asia, and maize and the potato in tropical America. By this time man had also learnt the usefulness of animals as a source of food and clothing. At first he went out to hunt for

them but later he learned that they could be domesticated. He probably noticed that where the animals dropped their excreta the plants grew more luxuriantly. This led him to apply animal excreta to his fields. This was the discovery of the use of animal manure for the growing of crops. And herein lies the beginning of the development of the art of farming. This probably was the condition of farming in most parts of the country about the time when the Aryans came to India. And although the people of India, through generations of farming, have been able more or less to develop the art of farming, yet the development of scientific agriculture has been the result of only very recent efforts.

Development of Agriculture in India—Scientific agriculture really began when India started to grow certain crops for which there was some demand over and above that needed for home consumption. The trade with the East India Company encouraged the growing of certain crops for export. During the administration of the East India Company, it actually stimulated the growing of certain crops like cotton and sugarcane for export to meet the "home" demand. But the formation of a definite agricultural policy began after the administration of India was transferred to the British Crown. The idea was really started after the report of the Bengal and Orissa Famine Commission during the administration of Lord Lawrence, although it was not taken up until the time of Lord Mayo, when the creation of an agricultural department was considered. The Manchester Cotton Supply Association more or less forced the issue on the Government in order to encourage the growing of cotton. So in 1870 a Department of Agriculture with Revenue and Commerce was established with Mr. A. O. Hume as Secretary. This department did not live long as it was eventually absorbed by the Revenue Department. But once again on the recommendation of the Famine Commission of 1880, the department was brought into existence. One of the main objects of this re-created department was the general improvement of Indian agriculture with the view to increasing the food supply of the people. The proposals of this Commission greatly influenced the agrarian policy of the administration in India for the next twenty years.

Another step forward was made when Dr. J. A. Voelcker of the Royal Agricultural Society, England, was appointed to investigate the

agricultural conditions in India, and on his submitting his findings entitled "Report on the improvement of Indian Agriculture". About this time Lord Curzon assumed the Viceroyalty of India and it was to his administration, acting on the recommendation again of another Famine Commission, that of 1901, and the report of Dr. Voelcker that we owe the development of agricultural departments working on scientific lines for the improvement of agriculture. This Commission pointed out at the time that "the steady application to agricultural problems of research is the crying necessity of the time".

In 1903 the Government of India submitted to the Secretary of State, a scheme for the establishment of an agricultural research institute, which scheme was approved of. About this time Henry Phipps of Chicago (U. S. A.) visited Lord Curzon and made a donation of £ 30,000, to be applied to some object of utility, preferably connected with scientific research. As a result of this, a research station with fully equipped science laboratories was started at Pusa in the Darbhanga district of Bihar. Later in 1912, an Imperial sugarcane breeding station was established at Coimbatore as a branch of the Imperial Research Institute at Pusa. After the earthquake of 1934, the Agricultural Research Institute at Pusa was moved to New Delhi.

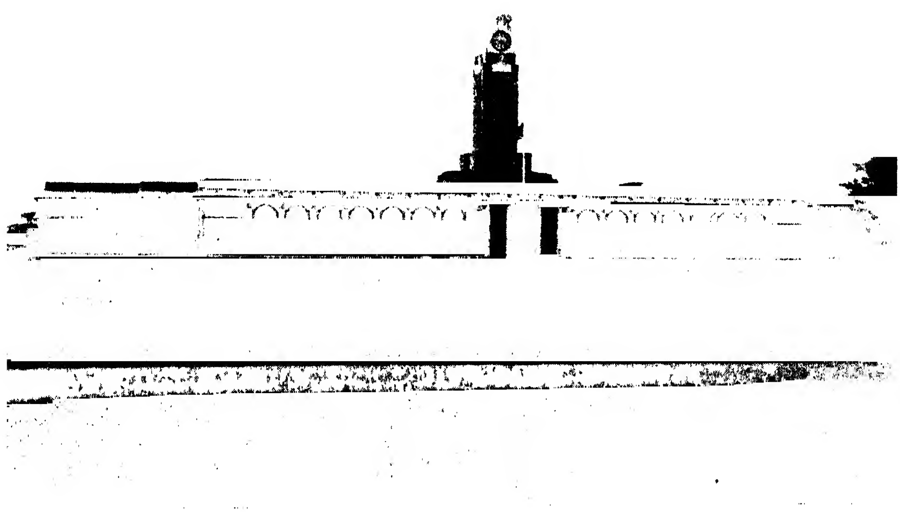

FIG. 1.—Linlithgow Library, the central building of the I. A. R. I., New Delhi.

For the development of agriculture in the provinces the Government of India in 1905, set aside Rs. 24,00,000 with the help of which experiment stations were started at important centres of agricultural tracts and agricultural colleges were either started or reorganized at Poona, Cawnpore, Coimbatore, Lyallpur, Nagpur, and Sabour. Since then the college at Sabour has been closed, and three non-Government colleges have been started, namely the Allahabad Agricultural Institute in U. P. founded by Dr. Sam Higginbottom, the Udaibhan Jat Intermediate College (Agriculture) at Lakhaoti, Bulandshahr district, U. P., and the Khalsa College, Amritsar, Punjab. This was again followed by the organization of the agricultural departments in all of the provinces in India.

In 1921 the Government of India took up the question of development in cotton growing as regards increasing of yield, and improving the quality. As a result of this the Indian Central Cotton Committee was officially established in 1923 as a permanent body with funds of its own and authority to undertake specific work. One of the first things that the Indian Central Cotton Committee did was to sanction in 1924 the establishment of the Institute of Plant Industry, Indore, as the central agricultural research station for cotton work, the cost of which is being met partly by the Indian Central Cotton Committee and partly by the Central India and Rajputana States. Parallel to this, the Technological Research Laboratory at Matunga in Bombay was established mainly for cotton work.

Another big step forward in the advancement of agricultural science in India was made when the Royal Commission on Agriculture in India was appointed during the Viceroyalty of Lord Irwin. The Commission was ably presided over by Lord Linlithgow.

The main object of this Commission was specifically to examine and report on the conditions of agriculture and rural economy. The Commission made very far-reaching recommendations, which will, for a long time to come, influence the policy of agricultural development in this country. Consequent to this report, the Imperial Council of Agricultural Research was set up for co-ordinating the work of agricultural research in this country, as it was found that there was a great lack of co-ordination between the Imperial Research Institute

and the provincial agricultural departments, and also among the provincial departments themselves.

This is in brief the progress of agricultural development in India.

Importance of Agriculture in India.—In order that one may be able to appreciate the fact that agriculture is the premier industry of this country, a table is given below showing the percentage of people engaged in the different occupations in this country. The figures are compiled from the census of 1931.

TABLE I

Percentage of total workers actually employed in different occupations.

Occupation.	Percentage.
Agriculture	67·1
Minerals	0·2
Industry (Textile, Hide, Ceramics, Food Industries, Furniture, Buildings, etc.)	10·0
Trade	5·1
Public Force	0·6
Public Administration	0·7
Transport	1·5
Professions and Liberal Arts	1·5
Miscellaneous	13·3

The figures given in the above table, should be noted, represent the percentage of the actual workers only. The number of people dependent on agriculture has been computed to be about 75 per cent. The next two tables are given to show the percentage of the population living in both urban and rural areas in British India and the Indian States respectively and also in the respective provinces.

TABLE II

Compiled from the census figures of 1931.

	Urban population.	Percentage of the total population.	Rural population.	Percentage of the total population.
British India ..	26,658,469	9 9	241,868,464	90·1
Indian States ..	9,326,958	11·5	71,983,887	88·5
Total ..	38,985,427	11·0	313,852,351	89·0

TABLE III

Compiled from the census figures of 1931.

	Urban population.	Percentage of the total population.	Rural population.	Percentage of the total population.
Madras ..	6,337,256	13·6	40,402,851	86·4
Bombay ..	4,202,578	23·4	13,789,475	76·6
Bengal ..	3,684,330	7.4	46,429,672	92·6
U. P. ..	5,421,621	11·2	42,984,142	88·8
Punjab ..	3,067,464	13 0	20,513,388	87·0
Bihar ..	1,152,117	4·5	24,575,383	95·5
C. P. and Berar .	1,688,470	10·9	13,819,253	89·1
Assam ..	213,421	2·5	8,408,830	97·5
N. W. F. Province	386,177	15·9	2,038,899	84·1
Baluchistan ..	92,025	19·9	371,483	80·1
Delhi ..	447,442	70·3	188,804	29·7
Sind	699,307	18·0	3,187,763	82·0
Orissa ..	191,429	3·6	5,114,713	96·4

These figures indicate that India's greatest industry is agriculture and promises to remain so for many years to come.

The great importance of agriculture to this country may also be realized if one examines the value of some of the agricultural products exported to other countries. The following table shows that the amount of money that is brought into this country from the export of agricultural products is enormous.

TABLE IV

The most important agricultural products exported and their value, 1934-1935.

Name of article of export.		Value in rupees
		Rs.
Cotton	Raw and waste	34,99,33,933
	Manufactured yarns	2,64,80,217
Tea		20,13,19,311
Grains, pulse and flour		11,84,39,874
Jute	Raw	10,87,10,916
	Manufactured	21,46,83,177
Seeds, including nuts for oil		10,54,09,836
Hides, skins and leather	Dressed	3,13,06,743
	Undressed	5,47,88,328
Gums, resins and lac		3,45,36,353
Oil cakes of all kinds		1,96,98,928
Fruits and Vegetable		1,07,78,117

One should not forget, however, that this is only a portion of the total produce, as much of it is consumed in the country itself. It may also be mentioned that there has been a very considerable decline in the exports to foreign countries especially in the case of jute, cotton, rice, tea, oilseeds and wheat during the last few years. Thus, while

the total value of the principal commodities, mainly agricultural, exported from India during 1929-1930 it was Rs. 311 crores, in 1930-1931 it was Rs. 220 crores and in 1931-1932, only Rs. 155 crores.

What is meant by Indian Agriculture ?—Considering the subject of Indian agriculture, one should not forget, as has been mentioned in the preface that there is really no such thing "as Indian Agriculture". Agricultural conditions in India vary so much from place to place that it is impossible to treat the subject as a homogeneous whole. India extends from the Himalayas, where conditions may be found to be similar to regions near the poles, to Cape Comorin, a few degrees north of the equator. Again it extends from Sind, and Western Rajputana where desert conditions exist, to Assam, including the regions with the greatest rainfall in the world. While some areas are famine stricken, others are so wonderfully rich that three crops a year are easily obtained from them. Again there are districts where money can be had in abundance, and where, therefore, the most modern agricultural machinery is found; while in some districts people are so poor and backward that only a primitive type of agriculture is practised. The subject is therefore of very great complexity and of a very varied nature, differing in different parts of the country.

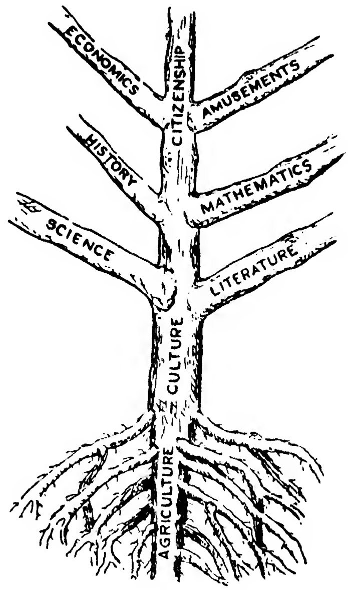

FIG. 2.

Agriculture and its relation to other subjects.—Whereas agriculture, as a science, is more or less a recent development, the art of raising crops as well as animals is almost as old as man himself. The science of agriculture within recent years has so developed that it has drawn into its province almost all the modern sciences and arts. With a little study of agriculture one soon realizes that it is not a simple subject but rather a very complex one. Some people who are not acquainted with the subject usually consider that agriculture is the meagre knowledge that a village farmer usually possesses. But the more one studies this subject, the more he realizes

its complexity and its far-reaching inter-relationship with other sciences and industries. In order to convey the conception of this complexity to the mind of the reader, the diagram on the preceding page is given which more or less represents graphically that inter-relationship of agriculture with other subjects.

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CHAPTER II

THE PLANT BODY AND ITS WORK

As students of agriculture will not be able to understand certain matter pertaining to crops unless they have some understanding of certain principles of plant growth, this brief discussion dealing with the different parts of the plant and their functions is given here. For the proper understanding of this book it is not essential for an agriculturist to study the detailed structure of the plant, but one should know what functions are carried on by various parts of the plant and how certain factors influence the plant. It is believed that the subject matter of this chapter will enable the agriculturist to acquire a better understanding of the principles underlying the better methods of agriculture.

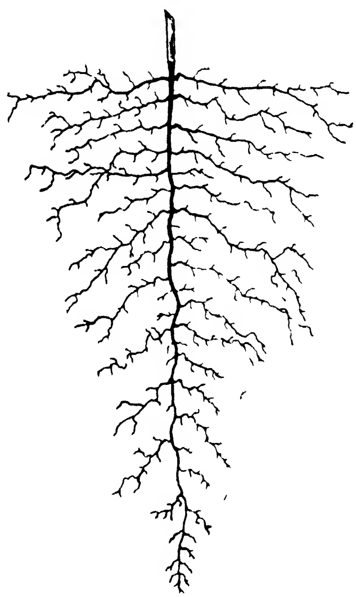

FIG. 3.—Tap Root System

In dealing with plants one should constantly keep in mind that he is dealing with living organisms. And just as animals respond differently to different factors of the environment, in the same way plants also are equally sensitive to temperature, sunlight, darkness and various kinds of nutrition. In other words, a plant is a living, growing thing, and makes the most of every opportunity that is afforded to it. It propagates its kind, just as animals do, and covers the face of the earth.

The plant as a whole may be divided into two parts: (1) the root and (2) the shoot. The shoot again consists of stems, leaves, flowers, fruits and seeds. Each of these has different functions to perform. And it is the intelligent understanding of the work of these parts of the plant that makes a brief treatment of this subject desirable at this point.

The Root.—The root system of plants is usually of two kinds: (1) the tap root system, which consists of a strong leading central root which runs directly downwards, and (2) the fibrous root system in

which is found a mass of slender and thin roots of nearly equal size. Examples of the first type are the root systems of radish (Hindustani: *muli*), lucerne or alfalfa (Hindustani: *luson*), castor (Hindustani: *arendi*), cotton (Hindustani: *kapas*), and pigeon pea (Hindustani: *arhar*, or *tur*), Examples of the second type are root systems of wheat (Hindustani: *gehun*), barley (Hindustani: *jau*), maize (Hindustani: *makka*), sugarcane (Hindustani: *ganna*), sorghum (Hindustani: *jowar* or *juar*) and most of the grasses. There are, of course, various other modifications, the most important being fleshy roots, such as the sweet potato (Hindustani: *shakarqand*).

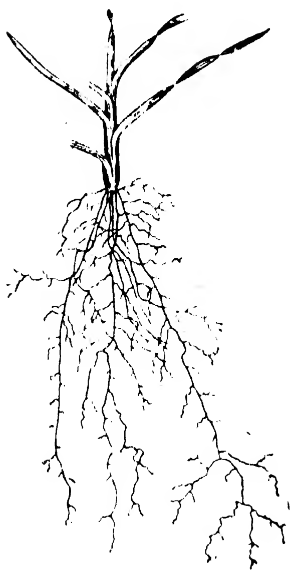

FIG. 4.—Fibrous Root System

The main functions that the root performs are: (1) anchorage, that is fixation of the plant to the soil, (2) the absorption of water and food materials from the soil. Other less important functions of the root are storage and reproduction. Besides, there are occasionally found roots that help the plant to climb, such as the roots of betel vine (Hindustani: *pan*), and aerial roots which have other functions besides anchorage and the absorption of food from the medium on which they grow, as in the case of the banyan tree.

As a rule, plants with the tap root system can support themselves better than those with the fibrous root system, as the former can fix themselves more firmly to the soil. One of the reasons why certain plants, such as sorghum and wheat, lodge is because their root systems are shallow. The question of lodging will be dealt with later in connection with those crops that are susceptible to lodging in the appropriate chapter.

But the most important work that the plant has to perform is that of absorption of food materials from the soil. This work however, is not done by ordinary roots but by special rootlets called root-hairs which are so fine that one can see them with difficulty with the naked eye. These are usually found just behind the growing tips of the roots. One can easily get acquainted with these by putting some seeds like those of maize for a few days on moist blotting

paper and allowing them to germinate. These are the special absorbing organs of the root, and it should be noted that they are near the ends. The large roots function as conducting channels through which water and substances in solution pass. These root-hairs absorb materials from the soil water through the process of osmosis, a special case of diffusion, and not by swallowing soil particles as some earlier people believed. These root-hairs are very delicate but are firmly attached to the small soil particles. In removing plants from the soil

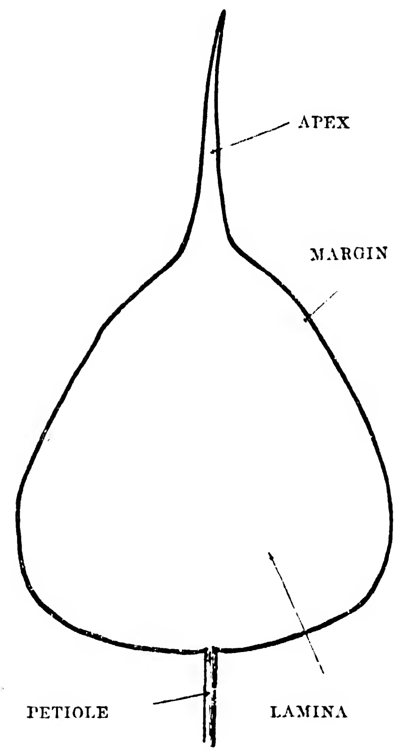

FIG. 5.
Leaf and its parts.

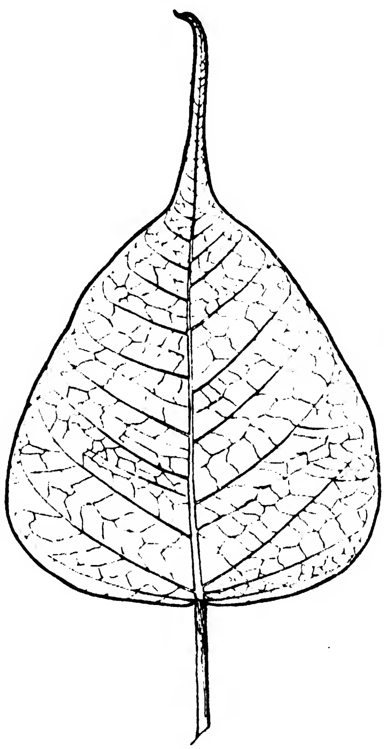
FIG. 6.
Netted—Veined Leaf.

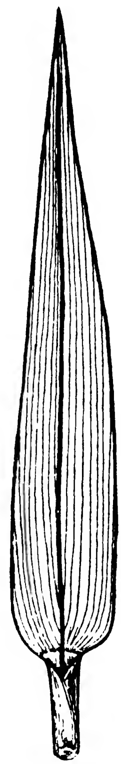
FIG. 7.
Paralleled-Veined Leaf.

for transplanting or for any other purpose the root-hairs are quickly destroyed. Hence care should be taken during transplanting that soil remains around the root so that these useful organs of absorption be not destroyed.

The root and the leaf are the two most important vegetative parts of the plant, and it is therefore the leaf, a portion of the shoot which will be discussed next,

The Leaf.—Before dealing with the important functions which the leaf performs the external features of the leaf will be briefly mentioned.

A leaf consists of the blade and petiole. The blade is a broad, flat and thin portion and which is the seat of the important activities of the leaf. This is usually green in colour and has a system of veins which are usually of a stouter texture than the rest of the blade. This is sometimes attached directly to the stem but is usually supported by a stalk known as a petiole, whose function is to hold out the blade in a favourable position for the performance of its activities. The petiole functions also as a channel for the conduction of water and food between the blade and other positions of the plant. Leaves vary widely in size, shape, form, venation, and other characters. Some leaves are netted-veined while others are parallel-veined. All the grasses, such as wheat, maize, *jowar*, sugarcane and rice, possess leaves with parallel-veins. The leaves of some plants, such as cotton, castor, and groundnut possess leaves with netted-veins.

One of the most important functions of the leaf is the manufacture of food from carbon dioxide and water with the aid of energy derived from sunlight, in presence of a green colouring substance which is present in the leaf and known as chlorophyll. This process of food manufacture which is performed by the leaf is known as *photosynthesis*. The food manufactured by this process is known as carbohydrate and consists mostly of sugar and starch. Besides the manufacture of carbohydrates the synthesis of proteins and fats is carried on to a large extent in the leaf. In short, it may be said that leaves are very important food-making organs of the plant.

Leaves also perform the important task of transpiring water (losing water) from the plant. Under normal conditions within the plant there is a continuous stream of water from the roots to the leaves. This process of the rise of sap is important in that food materials from the soil are carried upwards to the various parts of the plant. The rate of transpiration is greatly influenced by such external factors as humidity of the atmosphere, wind velocity, temperature of the surrounding air and intensity of light.

The Stem.—Another important vegetative organ of the shoot is the stem. This is the portion of the plant which connects the root with

the leaf. The functions of this organ are the following: (1) the support and display of leaves and flowers in favourable positions for the performance of their respective functions, (2) the transportation of materials to and from various parts of the plant, (3) in certain plants, vegetative reproduction, and (4) there are some plants whose stems function as storage organs.

The function of support and display consists in bearing the weight of the leaves, flowers and fruit, and in distributing them in space so that they are in positions favourable for the process of photosynthesis in the case of leaves, and for proper development in case of fruits and flowers. Plants can grow luxuriantly where there is an abundance of sunlight; hence the elongation of stems in order to expose the leaves to sunlight is very beneficial and essential for the plant. Such plants, therefore, as have weak stems, for example beans and peas, are able to secure more light by climbing on some support. The display of the flowers on the stem favours the transference of pollen for the proper setting of fruits and seeds through the processes known as pollination and fertilization.

The conducting function of the stem involves the transportation of water and other materials absorbed by the roots from the soil and the exchange of food and other materials in the various parts of the plant. This work in the stem is done by the conducting tissues. In grasses and allied plants (monocotyledons) these conducting tissues are distributed throughout the stem. These can be best seen in such plants as sugarcane, maize and *jowar*. The stringy portions of the stems of these are mostly composed of these tissues. In other plants (dicotyledons) these tissues occur just beneath the bark. It is this arrangement of these tissues in the second group of plants which makes the practices of grafting and budding possible. For this same reason it is possible to kill plants belonging to the second group by the process known as girdling, as this severs the conducting system, which results in the death of the plant. In the same way plants of this group may survive even after the inner portion (heart) of the plant has decayed or been removed.

It is a fact well-known to agriculturists that certain plants are able to propagate themselves by means of their stems. This fact is made use of by farmers and gardeners in the propagation of such plants by using portions of stems taken from them. This practice is followed in

the propagation of sugarcane, potatoes, roses, sweet potatoes and many other plants. This method has the advantage over the usual method of propagation by seed that the plant is able to "breed true", that is, plants may be secured which are true to type. Another advantage is that plants propagated in this way develope more rapidly than plants grown from seeds. In the practice of budding and grafting also this fact is made use of to produce plants which are true to type. Plants from seed vary more or less from the parent plants.

Stems of certain plants are especially adapted for the storage of food, although food is found in nearly all stems. Such plants as sugar cane and some kinds of sorghum contain large quantities of sugar in their stems while plants like the potato contain considerable amounts of starch in their underground stems. It is this stored material that makes them valuable for food.

The Flower.—The flower in crop plants is the organ of sexual reproduction. It is in this organ that the seed is developed. It seems probable that nature in order to help the plant perform this important function of reproduction, has produced flowers of various forms and colours. While some plants are able to reproduce vegetatively the principal way in which most crop plants reproduce is by means of seeds. Seeds are the product of flowers. A flower usually consists of four parts, namely, the calyx, corolla, stamens and pistil. The calyx is the lower and outer portion of the flower and is usually green in colour. It is composed of certain leaf-like structures which are known as sepals. The corolla is the most prominent part of the flower. This is usually highly coloured and is generally made up of parts known as the petals. The stamens are made up of a stalk which is called a filament and a larger portion at the top which is the anther and which bears the pollen grains. The pistil is composed of the ovary, the style, and stigma. The ovary is the enlarged portion at the base of the pistil and the slender upward projection above the ovary is the style. The upper portion of the style is known as the stigma.

The stamens and pistils are the essential parts of the flower, in that the former bear the pollen grains which are the male elements and the latter the female elements which include the ovary in which the seeds are borne. While the other parts of the flower are considered

to be accessory or non-essential portions, yet they help to provide protection to the essential organs. And the sepals and petals often attract insects, thereby helping in the process of pollination.

While in most plants the male and female elements occur in the same flower, in some plants such as maize they occur on different parts of the plant. In some others such as papayas, the male and female elements usually occur on different plants.

For the proper development of fruits and seeds it is necessary for the male elements, that is the pollen grains, to come in contact with the female element, that is, the stigma. This process of the transference of pollen grains from the anther to the stigma is known as *pollination.* The act of the union of the two male and female reproductive elements in the flower is known as *fertilization.* It is usually only after fertilization that the proper development of the fruit and seed takes place.

The Fruit and Seed.—The mature ovary with its attachments is known as the fruit in which the seed are enclosed. Seeds are developed from the structures in the ovary known as ovules. In most cases it is quite easy to distinguish between a seed and a fruit, but there are certain "seeds" which are botanically fruits. Now, tomatoes are fruits, and so also are the pea pods. These are easily known. But in addition to these a grain of wheat or a kernel of maize is also in the botanical sense, a fruit. In the latter two the ovary wall has become thin and dry, adhering very tightly to the seed, forming what is known as "dry" fruits. Usually fruit is known by the remains of some of the flower parts attached to it. The development of the ovary takes place immediately after fertilization and this results in what is popularly known as the "setting" of the fruit. Simultaneously, with the growth of the ovary, the development of the seed takes place. As most of the crop plants that are dealt with in this book are more concerned with production of seeds, it is desirable, therefore, that the discussion of seeds be taken up next.

Seeds are useful to man in many ways. Seeds of rice and wheat (a fruit known as a caryopsis), sorghum, gram and groundnuts are all used by man as food. Some seeds are also used for the production of various oils and fats such as linseed (H=*alsi*), cotton seed (also for fibre) sesamum. (H=*til*) and seeds of the castor oil plant. The seed

is also the structure by which most plants multiply themselves. The seed contains the germ or miniature plant and stored food which is necessary for its development during the period of germination and the primary stages in the development of the seedling. This food is commonly in the form of starch which provides energy for the growth of the young seedling during germination which is the process by which the germ or embryo begins its active growth. In order that proper germination of the seed should take place, the following conditions are necessary: (1) an adequate supply of moisture, (2) a suitable temperature, (3) the presence of oxygen.

Water is necessary in order that the embryo may break through the seed covering more easily. Water also helps the oxygen to enter the seed by diffusion.

While a certain degree of warmth is necessary for the sprouting of the seed yet different plants have different requirements of temperature for their best growth. It has been found that the optimum temperature for germinating seeds of wheat, barley, oats, peas, and linseed is between 77 and 88 degrees F.; while that for maize, cucumber (H=*kheera*), melon (H=*turbuz* and *khurbuza*) and lucerne, is from 88 to 99 degrees F.

The germinating power of seeds is dependent to a great extent on their vitality. There are several factors which influence the vitality of seeds. Some of these factors are the following: (1) The maturity of the seed—immature seeds quickly lose their vitality. Seeds of maize when immature usually produce plants which are weak and may therefore be more susceptible to diseases. This weak and unhealthy condition usually results in low yields. (2) The age of seeds—the vitality of seeds decreases with age. Some seeds, however, deteriorate more rapidly than others. Most seeds of our crop plants deteriorate so rapidly that they should not be sown after they are two years old. Seeds of wheat, maize and barley are known to be good for sowing if they have not been kept for more than two years. Seeds of such plants as peas, cabbages, mustard, pumpkin and many of the leguminous plants may safely be used for sowing even when they are three to four years old. However, it is a good practice always to sow seeds which are not more than one year old. (3) The conditions of storage—that is seeds that are stored properly retain their vitality for a longer period than

seeds which are improperly stored. For the best results seeds should be stored in a cool dry place and protected from insect attack.

The following table gives the result of the testing of the vitality of crop seeds in its relation to age as given by K. M. Sonavne of the Seed Testing Section, College of Agriculture, Poona.

TABLE V

Common name.	Botanical name	Germination percentage.				
		1922	1923	1924	1925	1926
Bajra	Pennisotum typhoideum	94·5	93·6	89·1	87·0	61·2
Jowar	Andropogon sorghum ..	89·7	90·7	90·8	84·5	79·1
Wheat ..	Triticum sativum ..	97·6	98·2	97·3	99·1	98·1
Maize ..	Zea Mays	96·0	97·3	96·2	89·6	86·7
Tur or *arhar* ..	Cajanus indicus ..	93·5	89·2	91·1	88·1	87·1
Mung	Phaseolus radiatus ..	77·2	93·6	97·1	94·5	96·7
Moth	Phaseolus aconitifolius ..	90·2	93·8	93·7	91·6	93·3
Urd	Phaseolus mungo ..	72·2	98·1	97·3	97·7	98·3
Gram	Cicer arietinum ..	96·6	99·8	98·0	93·2	97·5
Hulga kulli ..	Dolichos biflorus ..	99·0	98·5	98·2	98·1	97·6
Kabuli gram ..	Cicer arietinum ..	97·0	99·0	98·7	96·7	97·2
Cotton ..	Gossypium neglectum ..	58·6	67·3	58·0	55·8	53·3
Groundnut (Small Japan).	Arachis hypogea ..	92·6	74·5	60·2	28·5	23·8
Safflower ..	Carthamus tinctorious ..	97·3	98·5	96·6	96·6	94·7
Til ..	Sesamum indicum ..	85·6	85·8	85·6	79·2	80·5
Linseed ..	Linum usitatissimum ..	98·0	97·3	93·7	94·1	93·1

While these figures in the above table indicate that there is generally no deterioration in vitality with age, it should not be inferred that it is good agricultural practice to keep seeds for a period of more than two or three years. The method of storing of the above samples is quite different from the one usually adopted by an ordinary

cultivator. It does show however that seeds properly stored can retain their vitality for a considerable length of time.

Whenever possible it is advisable to test seeds for their vitality before sowing in order to find out what percentage of the seeds could be expected to germinate. Poor seeds are usually responsible for poor germination and consequently for a poor stand resulting in lower yields.

There are several methods for testing the vitality of seeds. The following method is one that can be easily adopted on account of its simplicity. In order to carry this out, no special equipment is needed except a piece of old cloth usually about 14 or 16 inches wide and about 3 or 4 feet long depending on the number of seeds to be tested. Care should be taken to secure a representative sample. Usually three lots of 100 seeds each are taken. First the cloth is moistened with water and then spread out. Seeds are then arranged in rows of three lots (say). Next the cloth is folded, on each side until the edges meet in the middle. After this the cloth is rolled up carefully so that seeds do not fall out or move from their places. The cloth along with the seeds is now placed in a warm place for two or three days usually depending on the kind of seed. Care should be taken to keep the cloth moist during this period, otherwise, proper germination will not take place. At the end of this period the cloth is unrolled carefully and spread out. The germinated seeds are then counted. The average of the three lots of germinated seeds gives the percentage of germination. This is known as the RAG DOLL TESTER METHOD.

The Relation Between Root and Shoot.—In the beginning of this chapter mention was made of the fact that the plant consists of two parts, the root and the shoot. The work of these two is very closely inter-related, and therefore, in order to have a proper development of the plant the maintenance of a proper balance is very important. If either one of these is too greatly reduced or too great in extent the other will not thrive. The practice of removing leaves from young plants during the process of transplanting is an effort to maintain this balance between root and shoot as in the removal of the plants from the soil some of the roots with their root hairs are destroyed, thereby reducing the absorbing system.

The Naming of Plants.—The same plant is known by different names in different parts of the country. And, on account of the difference

in language in different parts of the world, different names are applied. A plant known as sorghum is, for instance, known as *chari* in the Punjab, *juar* or *jundri* in the United Provinces, *jowar* in Central India and Bombay and *cholam* in South India. Scientists all over the world therefore have adopted a common system of naming plants which is known as the binomial system of nomenclature, according to which a plant has two, or rarely three names. The first is called the generic name or the name of the genus to which the plant belongs and the other is called the specific name or the name of the species. This is again usually followed by a letter or letters which represents the name of the person who first gave the name to the plant. This system of naming plants was started by Carl Von Linne, better known as Linnaeus, the great Swedish naturalist. Thus potato (H—*alu*) is given the scientific name of *Solanum tuberosum*, L., *Solanum* being the generic and *tuberosum* the specific names respectively, and L. standing for Linnaeus who first gave the name to the potato plant. This system does away with a great deal of uncertainty as to which plant is referred to, as this is the name by which the plant is known throughout the whole scientific world.

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CHAPTER III.

THE SOIL AND ITS IMPORTANCE TO AGRICULTURE

It is impossible to study agriculture without a proper understanding of the soil. The soil and the atmosphere together make up the environment in which the plant grows, developes, and reproduces. Of these two, the soil is probably the more important, as it is from it that the plant secures most of its essential nourishment. It is for this reason that its origin, development and its important characteristics are briefly discussed here. The study of soil began in very early times. Soil descriptions were already in existence in the seventh century before Christ. Men doubtless very early made certain observations about the soil, beginning when they began to use it in producing crops. But the science of soil, pedology, or edaphology, has only very recently developed, through the work of such men as Docuchaiev and Glinka in Russia, Ramann in Germany, and Hilgard in America. This study has shown that soil is very complex and yet at the same time one of the most interesting, and most wonderful things in nature.

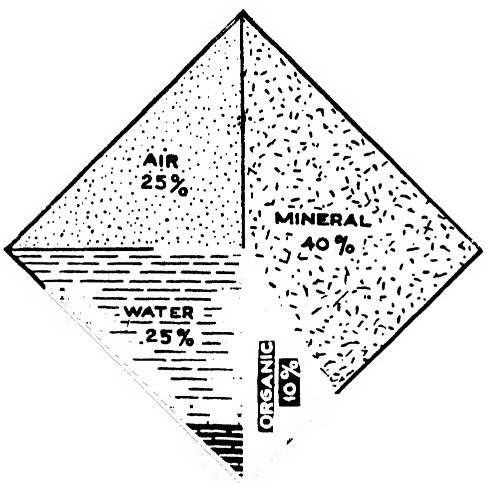

FIG. 8.—Average Composition of Soil.

The soil may be described as a thin layer on the surface of the earth's crust made up of the complex materials consisting of disintegrated and decomposed rocks, organic matter, substances in solution, water, air and such organisms as bacteria, fungi and protozoa. This is shown graphically in the above diagram

The figures given in the above diagram, are volume percentages, and it should be remembered, are only approximate, as the composition of the soil is not constant. In fact, every thing in the soil is dynamic, that is, in a state of continuous change and it is a mistake for one to

consider it to be static, *i. e.* not changing. Rock particles form approximately 90% of air-dried soil.

The development of these particles in order to form soil began in the unknown past; it took thousands and thousands of years before it developed to the state in which crop plants can grow. The small soil particles have been derived from solid rocks through processes known as mechanical disintegration and chemical decomposition, through such agencies as temperature, wind, running water, ice and animal and plant organisms.

Mechanical Disintegration.—Through changes of temperature, rocks expand and contract. Due to rocks being made up of a large number of minerals whose rates of expansion are different, this change in temperature sets up a considerable stress within the rock. This repeated expansion and contraction therefore, causes the formation of cracks in the rocks or the peeling or "flaking-off" of the outside layers of the parent rock; this latter process being known as exfoliation.

The *wind* is another factor which helps to a very great extent the process of soil formation. It possesses both erosive and transporting powers. Strong winds are able to pick up small rock particles and drive these against large masses of rock, thus cutting and wearing them away, thereby reducing them into small particles. The sand storms that usually occur in the drier parts of this country are examples of this activity.

Water possesses great power of erosion, when solid particles are suspended in it. A large number of our soils have been made by the cutting and carrying power of water. In temperate regions where ice and frost formation takes place, water usually enters into the cracks and crevices of rocks, which, when frozen, expands and breaks open the rocks. Running water also possesses transporting power, and is able to carry great loads of small rock particles. This transporting power of water has been calculated to vary with the sixth power of its velocity. Accordingly water is able to carry clay, silt, sand, pebbles, and stones depending upon its rate of flow. In this way water is able to sort and deposit different sizes of soil particles in different places. This sorting and deposition of soil materials is thus brought about by the increase and decrease in its rate of flow. Most of the soils of the Indo-Gangetic plain have been formed in this way.

Plant and animal organisms have also a considerable influence in soil formation. The activity of some of the lower plants, such as mosses and lichens which can grow on bare rock surfaces is very important in the early stages of rock disintegration and decomposition. These organisms send their tiny rootlets into the crevices of rocks and bring about a prying and loosening effect on the rocks.

The influence of animals which burrow holes in the soil, such as earthworms, termites, ants, mice and rats is also considerable. Their activities help to loosen and mix the soil. But the indirect effect of plants and animals is even more important than the direct effect. These plants and animals are responsible for the production of organic debris of all kinds and also in the formation of humus.

Chemical Decomposition of Rocks.—The subject of chemical decomposition of rocks has been studied from many different viewpoints by geologists, soil scientists and chemists. The first two groups of workers are interested in soil from the viewpoint of soil formatoin, while the last are mainly concerned with the complicated chemical changes which take place in the soil. This process of rock decomposition is brought about by oxidation, carbonation, solution and the activity of soil organisms and roots of plants.

Oxidation.—Is the action of oxygen on the various soil minerals. The action of oxygen on iron is exemplified by rusting, a phenomenon familiar to all. In soil containing iron compounds oxidation makes them fairly soluble. Most minerals in the rocks contain considerable iron which when oxidised help to weaken the rock. When the soluble compounds are dissolved in water the rocks are further weakened. This is illustrated by the following chemical reactions.

$$2\,FeS_2 + 7O_2 + 4H_2O = 2FeO + 4H_2SO_4$$

$$4\,FeO + O_2 = 2Fe_2O_3.$$

Carbonation.—Is usually associated with oxidation. Carbon dioxide which is found in small quantities in the atmosphere and in greater quantities in the soil air, when in combination with water forms carbonic acid. This is a weak acid but increases the dissolving power of water. In this way, chemical action on the rock masses forms soluble bicarbonates. This is shown by the following chemical reaction:—

$$2\,FeS_2 + 7O_2 + 4H_2O +_2 CO2 = 2Fe\,CO_3 + 4H_2\,SO_4.$$

Hydration.—Is the chemical union of water with other substances. This union also weakens rocks, thus bringing about their decomposition into soil. Hydration generally precedes or accompanies the processes of oxidation and carbonation. This process is usually accompanied by a considerable increase in volume, which may be as much as 88 per cent during the change from rock to soil. Hydration therefore, causes some of the rock-forming minerals to become soft and loose thereby quickly breaking down the rocks into soil. This change may be illustrated by the following chemical reaction which shows the change of the mineral hematite to limonite through this process of hydration :

$$2\,Fe_2O_3 + 3H_2O = 2Fe_2O_3 \cdot 3H_2O.$$

Solution.—The chemical decomposition of the rock minerals produces simple compounds which are usually more soluble. When these soluble compounds come in contact with water, solution takes place. This is due to the solvent action of water which is one of its important properties. Carbonate rocks such as limestone, magnesite and dolomite, are particularly susceptible to this solvent action of water, in the presence of other substances such as nitrates, chlorides and carbon dioxide. The following chemical formula illustrates this process :

$$CaCO_3 + CO_2 + H_2O \rightleftharpoons Ca(HCO_3)_2$$

Biological Activities.—The pioneer plants and animals did not live for ever on the same spot. They grew old and died, leaving as a contribution to the soil the substance—organic matter—of their dead bodies, including the elements secured from the rocks. This added wealth of decayed plant and animal tissues in the crevices in the partially disintegrated rocks created better feeding for the soil micro-organisms, such as bacteria and fungi. This supplied better feeding conditions for the higher plants. The simple products of decomposition of the substances thus made available to the higher plants by the action of these bacteria and fungi are carbon dioxide, water and ammonia. Certain bacteria are also responsible for chemical changes of various sorts, such as the transformation of nitrogen and its compounds, the results of which are of great importance to higher plants. Thus the conversion of nitrogenous organic matter into potassium nitrate is mainly due to the action of these micro-organisms.

Waste organic materials, especially those that are rich in nitrogen, when mixed with lime and in the presence of potassium carbonate are slowly converted into potassium nitrate and calcium carbonate, thus :

$$Ca\ (NO_3)_2 + K_2\ CO_3 = Ca\ \ CO_3 + 2KNO_3$$

The practice of composting farmyard manure is also dependent to a very great extent on the work of these micro-organisms. In short, without the presence of these organisms the soil would soon become unfit for the growth of higher plants.

ROCKS AND SOME IMPORTANT SOIL-FORMING MINERALS

Soil, as has been mentioned above, is made up largely of rock particles, which have been derived from the parent rocks. The character of these particles is similar to the parent rock from which they were derived. The rock particles have no inconsiderable influence upon the soil of which these are components. Geologists have classified rocks into three groups known as (1) igneous, (2) sedimentary, and (3) metamorphic rocks. Some of the soil-forming rocks and the group to which they belong are as follows:—

(1) Igneous: Granite, diorite, gabbro, syenite, diabase, peridotite.

(2) Sedimentary: Limestones, sandstones, shale and dolomite.

(3) Metamorphic: Marble, quartzite, schist, slate, and gneiss.

Igneous rocks are those which have been reduced to molten condition by intense heat in the interior of the earth and solidified in the crystalline form when they cooled down after they reached the upper part of the earth's surface.

Sedimentary rocks are those formed from the materials derived from the igneous rocks, and have been deposited generally under water.

Metamorphic rocks again, are either igneous or sedimentary rocks which have been subjected to heat and pressure and have been changed or metamorphosed.

Of these three the first group is the most difficult to break down, the other two being more easily disintegrated into soil particles.

The igneous rocks may again be classified into two groups: the acid and basic rocks. The acidity and basicity is due to the presence of

silica and alkalies respectively. Rocks belonging to the acid groups are the more difficult to break down. On this evidence H. O. Buckman has formulated what he calls the law of mineral and rock decay which runs as follows: "The more basic a rock becomes the more rapid is its decomposition; and the more acid, the less marked is its decay."

Rocks are complex bodies which are usually made up of minerals. These latter bodies in their pure state possess a definite chemical composition and are usually crystalline in form. By far the most common rock-forming minerals are either carbonates, silicates and sulphates. There are a great number of these minerals, but only a few are of practical importance from the agricultural point of view. Some of the most important soil-forming minerals and their relative amounts in the mass of the earth's crust are the following:—

1.	Felspars	48	per cent.
2.	Quartz	35	,,
3.	Mica	8	,,
4.	Talc	5	,,
5.	Carbonates of calcium and magnesium ..	1	,,
6.	Hornblende, Augite, Olivine, etc.	1	,,
7.	Other substances	2	,,

These various minerals are sooner or later affected by decay or chemical decomposition. Some undergo changes slowly, while others do so more rapidly. The insoluble minerals are decomposed into soluble salts—compounds which are oxidised, reduced or dehydrated. One of the most important chemical processes in the formation of soils is known as *kaolinization* or the formation of clay or kaolin from felspars. The importance of this process is due to the presence of clay in the great majority of soils. Clay determines to a considerable extent the physical properties of the soil for agricultural purposes, such as its suitability for growing certain crops. The formation of kaolin from anorthite, the lime felspar, may be represented by the following equation:

$$\underset{\text{(anorthite)}}{Ca\,Al_2Si_2O_8} + 2CO_2 + 3H_2O = \underset{\text{(kaolin)}}{Si_2O_5Al_2(OH)_4} + CaH_2(CO_3)_2$$

Orthoclase, the potash felspar, also undergoes a similar change, although the process goes on more slowly. It, however, is ultimately resolved into kaolin, as may be represented by the following equation:

$$2KAl\ Si_3O_8 + CO_2 + 2H_2O = Si_2O_5Al_2(OH)_4 + K_2CO_3 + 4SiO_2$$

(orthoclase) (kaolin)

Other minerals, besides felspars, upon decomposition, not only yield kaolin but also compounds of calcium and magnesium; and usually owing to the presence of a large number of complex silicates, both alkaline and metallic, some minerals like diorite and diabase sometimes decompose into green and brown clays. But the predominant red colour which is found in many tropical and sub-tropical soils is due largely to the presence of iron oxide, sometimes associated with manganese hydroxide, while the dark colour in soils is usually due to the presence of decayed organic matter, and not necessarily due to the colour of the rock material from which the soil is derived. The colour of the black cotton soils of Central India is due to other factors, which will be discussed in the chapter on the soils of India.

CLASSIFICATION OF SOILS

Soils have been classified in various ways They may be classified according to their geological origin, or according to their physical characteristics, or their chemical composition. Among the more recent classifications, soils have been grouped together according to their stages of development which again depend to a great extent on the effect of climate. For the purpose of this book, the geological and physical classifications will be discussed as these are the ones that are most commonly used.

The following is an outline of the *geological classification of soils.*

That is, soils are, according to this geological classification, divided into two main groups: (1) the sedentary soils, or soils that have not been moved from the place of origin, and (2) transported soils, or those that have been moved from their place of origin.

Sedentary soils are sub-divided into two groups known as *residual* and *cumulose* soils. The residual soils are those which are formed "in place," that is they originated from the underlying rocks. This group of soils is usually found in the hilly tracts. They can be easily

recognized by their characteristic profile. That is, these soils usually have the finer materials on the surface and the coarser material below underlaid by the parent rock. The surface material is usually in an advanced stage of disintegration. Cumulose soils are similar in origin to residual soils, but differ in character in that they are made up largely of organic matter with but small amounts of minerals. They are usually formed in marshy places. Cumulose soils are more commonly called peat or muck depending on their stage of decay. In *peat* soils the stem and leaf structure of the original material can be recognised while in *muck*, decay has gone further and this identity is lost.

Transported soils are those moved from their place of origin through such agencies as water, wind, gravity and ice. (1) Those that were transported by ice are called *glacial soils*. Such soils are commonly found in certain areas near the base of the Himalayas where they were brought down by the action of glaciers, such as the soils of the Dehra Dun region and parts of Kashmir. These soils are not of very great agricultural value in India, but are of considerable importance in other parts of the world, for example, the soils of the northern portion of North America. (2) Those that were transported by the action of gravity are called *colluvial soils*. These are usually made up of rock fragments generally at the bases of cliffs, and consist of materials brought down by land-slides. These soils are usually very poor, and are unfavourable for plant growth. (3) Those soils that had been moved by the action of wind, from their place of origin are known as *aeolian soils*. In some parts of the world these are commonly known as *loess*. These soils occupy great areas of China and Siberia. The adobe soils of California are also of aeolian origin. In India these soils are met with in parts of Rajputana, Baluchistan and the Salt Range of the Punjab.

Soils that were transported with the action of water are of three kinds: (1) *lacustrine*, (2) *marine* and (3) *alluvial soils*. The first type of these soils are found near lakes, the second occur near the sea coast, while the third group, which is by far the most important in India are found practically in the whole of northern India, where these soils were brought down by the net-work of the three great river systems, the Indus, Ganges and Brahmaputra. Near their places of origin, the materials deposited are generally very coarse, but as these rivers flow

more slowly, after leaving the mountainous regions, the finer materials that are carried by them begin to be deposited, as the carrying power of the water is decreased due to its decrease in velocity. As already mentioned, the carrying power of water has been calculated to be directly proportional to the sixth power of its velocity. This means that doubling the velocity increases its carrying power $(2)^6$ or 64 times. Due to the variation in the velocity of the water, different sized materials are deposited at different times. In this way, layers are formed which differ somewhat in their characteristics. This type of deposition in layers is known as *stratification*, and is a characteristic of alluvial soils. Another characteristic of alluvial soil is that the particles are more or less round in comparison with those of residual soils which are usually angular in shape. This is due to the fact that the sharp edges are worn down by the rolling, rubbing and grinding action of running water. These soils are usually of considerable depth, and are often composed of silt, loams and sandy loams. Sometimes finer materials are usually deposited as alluvial soils when streams overflow their banks, and the water becomes very sluggish and comes to a standstill. Such materials usually form clay soils. Generally alluvial soils occur as long narrow strips along rivers and streams or as "alluvial fans" at the base of mountains or as deltas where the rivers enter lakes or seas.

These soils are found in various parts of the world, and are probably the most important from the view point of agriculture.

Another method of classification and probably the one most commonly used by practical agriculturists is the one based upon the size of the soil particles. This may be called the "*textural classification of soils.*" By texture is meant the relative size of the soil particles. In this classification, soils are separated into the following main classes:

1. Gravelly soils ... (Hindustani = pathrili ar kankrili)
2. Coarse sands } ... H = ret
3. Fine sands }
4. Sandy loam ... H = retili domat
5. Fine sandy loam ... H = halki domat
6. Loam ... H = domat

7. Silt loam ... H=bhurili domat
8. Clay loam ... H=bhari domat
9. Silt ... H=bhur
10. Clay ... H=chikni matti

Of these ten groups of soils the first three and the last two are of little importance in agriculture. The gravelly soils and the sands are usually very poor for agricultural purposes because of their open and porous character. However, sometimes special crops adapted to these soils are grown, such as the watermelon in certain parts of Rajputana. Silts and clays are seldom found in the pure state ; and when they do occur in this manner, they are of little importance agriculturally. However special crops such as rice are sometimes grown on very heavy clays. The bulk of the agricultural crops are mainly grown on the loams. The loamy soils may be composed of clay, silt, sand and other soil materials in various proportions. In other words, they are mixtures of any two or more of these soil materials.

Soil scientists have assigned certain sizes to different groups of soil particles, which are technically called *soil separates.*

The following table gives the range of sizes of the different soil separates :—

TABLE 6

Soil separate	Size in millimetres
Fine gravel	1 – 2
Coarse sand	1 – ·5
Medium sand	·5 — ·25
Fine sand	·25 — ·10
Very fine sand	·10 — ·05
Silt	·05 — ·005
Clay	below ·005

The separation of the soil materials into these different groups of soil separates is performed by methods which are known as the *mechanical analyses of soils.* These methods are employed by soil specialists in laboratories, and are hardly meant for practical agriculturists. For this and other reasons, one method only will be mentioned by way of

general information. This method is probably the simplest and is known as the sieve method. The method consists of a series of sieves, each sieve possessing holes of equal diameters, but different from those of the other sieves of the series. The upper sieve in the series possesses the largest perforations. The material passing through it goes on to the next sieve and so on.

In this method the dry soil which should be free of lumps, is taken, and is then placed in the upper sieve and the whole series is shaken thoroughly until the particles are completely separated. The material in each lot is then weighed and calculated on the basis of percentage. For finer materials like silt and clay it is sometimes desirable to use a stream of water for washing the material through the perforations. However, silt and clay cannot be separated accurately by this method.

As previously mentioned, the loams are mixtures of two or more soil materials such as clay, silt and sand. The various loams are therefore made up of various percentages of these materials. The table given below gives the approximate percentages of these materials in the various loams.

TABLE 7

	Clay	Silt	Sand	Other materials	Total
Sandy loam	12%	21%	63%	4%	100
Fine sandy loam	12%	24%	63%	1%	100
Loam	16%	40%	42%	2%	100
Silt loam	15%	65%	19%	1%	100
Clay loam	26%	38%	35%	1%	100

The identification of soils and placing of them in these various classes, such as sandy loam, fine sandy loam, loam, etc , can be easily performed by one who has had some experience in field work with different soil classes. This is usually judged on the basis of colour and "feel". That is, colour will usually indicate the humus content and the parent soil material, while by rubbing the soil between the thumb and the fingers, the texture of the soil may be determined by

the grittiness of sand or plasticity of clay or "floury feel" of silt. This method is surprisingly accurate with one who has had considerable experience with soils in the field, and may in most cases be relied upon.

A key for the practical classification of mineral soils as given in "The Nature and Properties of Soils" (1922) by Lyon and Buckman, is given below.

I Soils possessing the properties of one size of particle largely :

1. Particles very large ... *Gravel*
2. Particles apparent to eye, feel gritty and non-plastic ... ... *Sands*
3. Particles very small, soil very plastic when wet, hard when dry ... ... *Clay or Sandy Clay*

II Soils possessing the properties of a number of sizes of particles—a mixture :

1. A fairly equal exhibit of sandy and clayey properties ... ... *Loam*
2. A mixture but with sand predominating *Sandy Loam*
3. A mixture but with silty character dominant. The soil has a "floury" or "talc feel" and is quite plastic when wet ... *Silt Loam*
4. A mixture but with clayey characters very apparent. Soil is very plastic and approaches a clay in character ... *Clay Loam*

Some of the Important Physical Characteristics of Soil

One of the most important characteristics of soil is its *colour.* This characteristic is an important aid in the recognition and description of the different soil groups. The colour of soils is dependent on many factors. Moisture is one of the many factors which affect the colour. That is certain soils change their colour in the processes of drying and wetting. The colours of most soils stand out more sharply when wet than when dry. The colour of moist soil is dependent to a considerable extent upon the amount of organic matter and

colloidal clay present in the soil. Usually soils containing a high percentage of organic matter are dark in colour. However, this dark colour imparted by organic matter may sometimes be masked by the presence of colloidal clay material. But the parent material from which the soil is derived and the mode of its formation often exert a considerable influence upon the soil colour. For instance, the red or yellow colour in soils is usually due to the oxidation of the iron in the original rock material. A soil which is deficient in organic matter with iron absent or unoxidised is usually of a light colour.

The colour of soils is generally a good indicator of their fertility or agricultural value; as the black or light-coloured soils indicate the presence or absence of organic matter which is an important constituent of soils. Red soils often indicate the low amount of humus in the soil. A person with even a little agricultural experience knows that the *surface soil* is usually of a darker colour than that of the *subsoil.* This peculiar characteristic is usually made use of in distinguishing between soil and subsoil. However, this line of demarcation is not so distinct in the case of soils of arid regions. The darker colour in the surface soil is very largely due to the higher content of decayed organic matter which is the residue of plants.

Another important physical characteristic of soils is their *density.* By this is meant the lightness or heaviness of soils. This usually depends on the texture of the soil. That is, soils possessing larger particles are usually heavier in weight per unit volume, while those with smaller particles are usually lighter. This should not be confused with the common idea that sandy soils are "light" soils, whereas, clay soils are called "heavy" soils. These later terms are applied by farmers to soils which are easy to cultivate or hard to work, respectively. Sandy soils are easy to work because they are granular and therefore loose in character, whereas, the clay soils are more plastic and, therefore, more compact in character.

The *plasticity* in soils is due to the presence of inorganic colloidal materials. This property enables soils to change in shape continuously when subjected to some applied force and to retain that shape when the force is removed. Plasticity is also closely associated with another property found in soils which is known as *cohesion.* This again, is the property which causes certain particles of soil to cling or cohere

to each other. This property is most marked in clay soils. The cracks which are found when clay soils dry out are largely due to this cohesiveness in such soils. This is also responsible for the formation of hard clods or lumps in fine-textured soils when the latter are ploughed.

Soil heat is another important physical property of soil. The sources of soil heat are many. A certain portion is brought to the soil through rain. A considerable amount is produced by the chemical and biological activities which take place within the soil. But the greatest amount of this heat is derived directly through radiation from the sun. The power of the soil to absorb heat is dependent upon a number of factors such as colour, texture, structure and slope. For instance, the darker soils possess greater heat absorbing capacity. The addition of organic matter such as farm manure to the soil will impart a dark colour to the soil and consequently increase its heat absorptive power. The texture and structure of a soil have some influence on the heat abosrptive capacity but their importance lies in the fact that these soils possess different capacities for water, which, in turn influences the heat capacity of the soil.

The slope of the land also influences the soil heat. For instance, the southern slopes usually are warmed more rapidly than those facing towards the north. This is true for the northern hemisphere only.

The soil heat and soil temperature are closely related and the two should not be confused with each other. Soil heat refers more or less to the quantity of heat contained in the soil, whereas, soil temperature simply refers to the degree of hotness or coldness of the soil. Thus the soil having a high heat capacity will rise or fall in temperature much less rapidly than one with a lower heat capacity. Soils possessing high heat capacity are usually spoken of as cold soils because such soils warm more slowly. For example, clay soils possess the ability to hold more water than sandy soils. And since water has a heat capacity which is approximately five times the heat capacity of the soil particles, therefore, clay soils generally possess a higher heat capacity. For this reason the temperature of the clay soil rises very slowly, consequently, these soils are spoken of by farmers as cold or late soils, whereas, sandy soils are spoken of as warm or early soils. In the same way the heat capacity of sandy soils may be increased by the addition

of water by irrigation. This will decrease the rapidity in the fluctuation of soil temperature.

While the temperature fluctuates very rapidly in the surface soil, at the depth of about one foot the fluctuation is very slight. According to Leather the diurnal change of temperature at Pusa in Bihar is only 1° centigrade at the depth of 12 inches but at 24 inches it is doubtful whether it ever exceeds 0·1° centigrade. He also found that the temperature of the soil at a depth of 3 or 4 inches is above the mean air temperature of the day only for about eight hours daily, whilst it is below it for about 16 hours.

The following table gives the comparison of air and soil temperatures taken at Pusa in Bihar (India) throughout the twelve months in the year.

TABLE VIII

	Maximum		Minimum	
	Air	Soil 1″ deep	Air	Soil 1″ deep
January	23·5 C	25·3 C	9·1 C	10·7 C
February	26·3 ,,	29·3 ,,	11·6 ,,	13·6 ,,
March	31·2 ,,	34·6 ,,	13·8 ,,	15·5 ,,
April	36·6 ,,	39·9 ,,	20·6 ,,	22·3 ,,
May	36·4 ,,	40·1 ,,	23·0 ,,	25·5 ,,
June	33·9 ,,	38·2 ,,	24·5 ,,	26·9 ,,
July	32·3 ,,	36·3 ,,	25·6 ,,	27·1 ,,
August	32·2 ,,	36·7 ,,	25·5 ,,	27·4 ,,
September	33·2 ,,	37·1 ,,	24·1 ,,	26·0 ,,
October	32·8 ,,	36·1 ,,	20·2 ,,	22·2 ,,
November	26·8 ,,	28·6 ,,	14·1 ,,	16·1 ,,
December	23·2 ,,	24·9 ,,	9·2 ,,	10·8 ,,

An examination of the above table will show that the minimum soil temperature at 1″ deep is always higher than the minimum air temperature, the difference being about 1·5° to 2°C (*i. e.* 2·7. to 3·6°F.). The second point to be noted is that the maximum soil temperature at

1" deep is always higher than the air temperature (in the shade), the difference being from 2 to 4°C (*i. e.* 3·6 to 7·2°F.). The third point to be noted is that the above soil temperatures were taken in the alluvial soil of the Gangetic plain in Bihar. The figures, therefore, do not apply to other parts of India and to other soil types such as the black cotton soils, which on account of their dark colour probably become hotter at the surface than the above figures would indicate. Another point to be noted is that these figures are monthly averages and therefore do not indicate the absolute extremes of both minimum and maximum temperature, nor do they indicate the absolute difference in temperature which occurs in any single day, as the averages tend to smooth out these differences. It may be expected that during the hot dry weather when the sky is clear, a condition which is usually found in many parts of India, the daily difference in temperature is probably much greater. During the monsoon however, when the sky is cloudy the difference between air temperature and that of the soil at 1" deep is very much reduced being probably not more than 2 to 3°C (*i. e.* 3·6 to 5·4°F.). These soil temperatures are also greatly affected by rainfall. This effect may be expected to be greater during the dry season than during the monsoon. It was also found that the effect of a crop especially one that almost completely covers the soil, such as cowpeas has a very marked effect on the soil temperature, as it prevents the temperature of the soil from rising to the same degree as occurs in the fallow land.

One of the most important physical properties of a soil from the agricultural point of view is the arrangement of its particles. This arrangement of the particles is known as *soil structure.* At least four different arrangements are generally recognised. The first is "columnar" that is one in which the soil particle is touched by its neighbours at four points. The second is the oblique arrangement in which the particle is touched at six points by its neighbours. The third is called the compact arrangement which is one in which smaller particles of soil occupy the spaces unoccupied in the more or less oblique arrangement, thus reducing the space between the particles. The puddled condition is an extreme form of this arrangement, in which the space between the particles is reduced to the minimum. This is detrimental to plant growth, as it prevents the proper circulation

of air and water. The fourth type of arrangement is known as granular. In this arrangement several particles come together forming a group which behaves more or less like a large soil particle, so that large spaces occur between such groups. Each group of particles functions more or less separately. This condition occurs only in fine-textured soils such as loam, silt and clay. This condition produces what is known as a crumb structure. A fine-textured soil may be prevented from being puddled by increasing the tendency towards granulation. Some of the practices which tend to develop a granular structure in soil are the addition of organic matter, or lime, and tillage.

The *soil air* is a physical component of soil and is only an extension of the atmospheric air into the spaces unoccupied by the particles in the soil. The soil air cannot move so readily as the atmospheric air due to the fact that it is locked up more or less in the empty spaces in the soil. This reduced movement of air in the soil produces variation in the composition of the soil air.

The following table is given in order to show the difference in composition between atmospheric air and that of an average soil air.

TABLE IX

	Carbon dioxide	Oxygen	Nitrogen and other gases
Atmospheric Air	·03	20·99	78 95
Soil Air	·20	20·60	79·20
Difference	·17	·39	·25

From the above table, it will be noted that the average composition of soil air is not materially different from that of atmospheric air. However, the soil air contains about seven or eight times as much carbon dioxide than atmospheric air. But there is a considerable variation in the amount of carbon dioxide in the soil air, depending to a very great extent on the type of soil or on the amount of organic matter added to it. It has been found, by Boussingault and Lewy for instance, that the amount of carbon dioxide in sandy soil ten days

after manuring is 9·74 per cent, which is approximately 324 times the amount of carbon dioxide in ordinary atmospheric air. J. W. Leather, working on soil gases in Bihar (India), gave the following composition of gas of three samples of swamp rice lands.

TABLE X

	Carbon dioxide	Oxygen	Nitrogen	Other gases
Sample A	4·34	·32	84·25	11·095
Sample B	4·23	·31	86·60	8·855
Sample C	4·69	·99	85·91	8·409

It will be noted from this table that the amount of oxygen is very much reduced under swampy conditions, while the percentage of carbon dioxide is very much higher than even in ordinary soil air.

The following figures are taken from J. W. Leather to show the composition of the soil air present in the neighbourhood of the roots of certain crops. The samples were taken at a depth of 3 to 6 inches.

TABLE XI

Crop	Dates when samples were taken	Carbon dioxide	Oxygen	Nitrogen
Sann hemp	27-7-14	16·99	2·23	79 77
,, ...	25-8-14	12·12	4·67	81·63
Maize	4-9-14	3·34	13·82	81·59
,, ...	10-9-14	12·30	7·25	79·47

The above figures show that the amount of oxygen near the roots of plants is much less than what is found in ordinary soil air, while, on the other hand, the amount of carbon dioxide is very high. It seems very probable that during the growth of the crop the soil air is used up by the roots and large quantities of carbon dioxide are formed. Another interesting point to notice in the above table is the difference in the amount of oxygen near the roots of sann hemp and that near

those of maize. Sann hemp is usually a non-cultivated crop, while maize is usually cultivated, and is also believed to be profited by frequent cultivations. Leather, however is of the opinion that the movement of gases in soils even down to the depth of 12 to 15 inches is so efficient that the cultivation of the surface soil is unnecessary for purposes of aeration, and that the well-established value of this agricultural practice must be referred to other causes.

Another factor which influences soil air in India is the *monsoon.* The rainfall filling up the spaces between the soil particles with water would tend to exclude air. Similarly irrigation also would tend to drive out soil air. But as the water moves downward a new supply of atmoshperic air is pulled in, thus facilitating the interchange of air in the soil.

In plant development a great variety of intricate physical, chemical, and biological factors are involved. On the resultant of all these factors depends the crop producing power of the soil. The Water in the plant functions in three ways. (1) Water is itself a form of plant food as some of it ultimately becomes chemically a part of the plant. (2) Water maintains the turgidity of the tissues. That is it helps to keep them in a rigid or inflated condition, which is necessary for the proper functioning of the plant. If this condition is not maintained, the plant collapses or wilts. (3) Water acts as a solvent and a carrier of plant food. It not only dissolves the various substances contained by the soil mass and makes them available for the plant but it also acts as a medium of transfer of these food materials from the soil to their proper places in various parts of the plant. Plants, it should be remembered, can only take their food materials in the form of a solute and never in a solid condition.

Three forms of soil water are generally recognized. The first is called the *hygroscopic water,* which is the moisture held by an air dried soil, or, in other words it is the moisture absorbed by a completely dried soil when exposed to the atmosphere. This form of soil water is held very tightly to the soil particles and therefore is not available to the plant. The second form of soil water is usually known as the *capillary water*, which is the moisture held in the spaces between the particles of soil over and above the hygroscopic film of

moisture and is held in place (*in situ*) against the force of gravity. This is the form of water which is most useful to the crop plants, exclusive of water plants (hydrophytes) such as rice, etc. The third form of soil water is known as *gravitational* or *hydrostatic* water. This is also known as "free" water. It is the form of water in the soil which moves freely in the soil mass under the action of gravity unless it is somehow otherwise restricted in its movement. This form of soil water is usually harmful to crop plants (mesophytes), if it remains long in the part of the soil occupied by roots, and useful only to water plants (hydrophytes).

B. A. Keen of Rothamsted and some others have suggested other methods of classification of soil water. In one of these methods of classification the capillary water is further divided into (*a*) pendular, (*b*) funicular and (*c*) capillary water. This classification is based on certain mathematical reasoning which lies outside the scope and purpose of this book

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CHAPTER IV.

CLASSIFICATION OF CROPS

For purposes of study, crops may be classified in various ways. They may be classified: firstly, according to their botanical relationships; secondly, according to their use; thirdly, according to their cultural methods; fourthly, according to the seasons in which they grow; and so on.

I. In the **botanical** classification, crops are classified as follows:

1. *Gramineae* or grass family:
   Wheat, rice, barley, *jowar*, oats, maize, *bajra*, sugarcane, and all of the millets.
2. *Leguminosae* or pea family:
   Gram, peas, *mung, urd, masur, sem, tur* and *arhar*, soybean, sann hemp, indigo, lucerne, *guara*, and various beans.
3. *Cruciferae* or mustard family:
   Cabbage, cauliflower, kohlrabi, turnip, radish, *taramira* or *seoha*, *rai, sarson*, *toria*, etc.
4. *Cucurbitaceae* or gourd family:
   Watermelon, cucumber, bitter gourd, *phut*, muskmelon, pumpkin, *kakri*, *chichinda*, etc.
5. *Liliaceae* or lily family:
   Onion, garlic, asparagus, etc.
6. *Solanaceae* or potato family:
   Potato, brinjal, chillies, tomato, tobacco, etc.
7. *Malvaceae* or cotton family:
   Cotton, *patsann*, roselle, *bhindi*, etc.
8. *Compositae* or sunflower family:
   Sunflower, artichoke, lettuce, niger, safflower, etc.
9. *Euphorbiaceae* or milkweed family:
   Castor, etc.

10. *Convolvulaceae* or morning glory family:
    Sweet potato, etc.

11. *Aroideae* or dasheen family:
    Arui, *kachalu*, *banda*, etc.

12. *Zingiberaceae* or ginger family:
    Ginger, turmeric, etc.

13. *Lineae* or flax family:
    Linseed, etc.

14. *Tiliaceae* or jute family:
    Jute, etc.

15. *Umbelliferae* or carrot family:
    Carrot, coriander, anise, etc.

16. *Onagraceae*:
    Singhara or water caltrop, etc.

II. In the **economic classification** all the crops are classified according to their use as follows:

1. **Cereals:**—This includes wheat, rice, maize, barley, oats, *jowar* and millets.
2. **Pulses:**—This includes gram, peas, *tur* or *arhar*, *urd*, *mung*, *masur*, cowpea, etc.
3. **Oilseeds:**—Linseed, niger, castor, groundnut, *toria*, *sarson*, *rai*, *til*, etc.
4. **Fibre crops:**—Cotton, jute, sann hemp, flax (linseed), etc.
5. **Sugar crops:**—Sugar cane, beets, etc.
6. **Fodder crops:**—*Jowar*, *bajra*, maize, Napier grass, Guinea grass, lucerne, clover, etc.
7. **Dyes:**—Indigo, safflower, etc.
8. **Stimulants or drugs:**—Tea, coffee, tobacco, poppy, *bhang*, etc.
9. **Spices:**—Coriander, ginger, turmeric, chillies, anise, cardamom, *supari*, etc.
10. **Root crops:**—Turnips, carrots, potatoes, beets, yams, sweet potatoes, radishes, etc.

11. **Vegetables:**—Brinjals, *bhindi*, tomatoes, beans, onions, garlic, cabbage, cauliflower, kohlrabi, lettuce, etc.

12. **Pot-herbs or greens (sags)**:—Spinach, fenugreek, etc.

13. **Fruits**:– Mango, papaya, orange, guava, jack-fruit, etc.

14. **Special purpose crops**:—Silage crops (*Jowar*, etc.) Soiling crops (*Jowar*, *bajra*, etc.) Green manure crops (Sann hemp, *guara*, etc.). Catch crops (*Bajra*, some cucurbits, etc.).

III. In the **classification according to cultural methods,** crops may be grouped as *irrigated* and *non-irrigated*. However there is not a very distinct line of demarcation between the two groups; as some crops may be grown under irrigation under certain conditions, and by dry-farming under other conditions. For instance, wheat may be grown with or without irrigation. Sugar cane also under humid conditions, such as those existing in Bengal and certain parts of Bihar, is grown without irrigation, but in most other parts of India it is being grown as an irrigated crop. In most parts of northern India, a crop that is grown without irrigation, is known as a "*barani*" crop. Crops may be grouped also according to whether they are cultivated or non-cultivated. Thus crops like potatoes and maize usually require interculture; while barley and wheat are usually considered as crops not requiring any interculture.

Sometimes again, certain crops are grouped together because of the similarity in their cultural treatments. Thus crops like carrots, radishes, turnips, beets, etc., although they belong to different families botanically, they are usually placed in one group which is known as root crops.

The other system of classification which is most commonly used in India, is based according to the seasons in which the crops are grown. Thus crops are classified as *kharif*, *rabi*, or *zaid* crops. *Kharif* crops are those which are sown in the beginning of the south-west monsoon, hence they may also be designated as monsoon crops. The *rabi* crops are usually sown in the beginning of the cold weather and may therefore also be designated as cold weather crops. The *zaid* crops are those that are sown in the beginning of the hot weather, and

are usually not considered to be as important as either the *kharif* or the *rabi* crops, and may therefore be designated as the inter-season or catch-crops. The following is a list of crops, grouped according to this system of classification. It will be noted that certain crops which require one or two seasons before they reach their maturity, have been placed in one or the other of the three groups.

Kharif crops:—*Jowar*, maize, rice, *bajra*, castor, sesamum, brinjals, chillies, tobacco, sweet potatoes, minor millets, *mung*, *masur*, *arhar* or *tur*, cowpeas, sann hemp, indigo, *moth*, *guara*, groundnuts, *sem*, soybeans, jute, *bhindi*, roselle, niger.

Sugar cane and cotton more naturally fall into this group also, although the former requires one year for its growth, and when left as a ratoon crop, more than one year.

Rabi crops:—Wheat, barley, oats, potatoes, peas, gram, *khesari*, linseed, mustards, cabbages, tomatoes, cauliflower, kohlrabi, turnips, onion, garlic, radishes, lettuce, beets, carrots, etc.

Zaid crops:—*Arui*, watermelons, muskmelons, cucumbers, pumpkins, *taroi*, and *ninua*.

IV. **Crops may also be classified into annuals, biennials or perennials**, depending on whether they complete their life cycle in one, two or more than two years. An annual crop is one which grows, matures and dies in the course of one year; whereas a biennial crop requires two years, and a perennial requires more than two years. Wheat is an example of an annual crop. The beet is more often a biennial crop if permitted to grow to its full development. It will not flower in its first year of growth but will do so only in the second year. Lucerne is a good example of a perennial crop as it is usually grown in this country for a period of five to six years, and in some parts of the world, like California, it is grown for a period of twenty to twenty-five years. But twelve years is the most common practice in that region. Sugar cane is normally an annual crop, but sometimes it is grown as a ratoon crop, in which case it becomes a biennial or a perennial crop. Similarly cotton may behave as an annual, biennial or perennial depending upon the type of cotton as well as the climatic conditions under which it is grown.

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CHAPTER V.

IMPROVEMENT OF CROPS

Anyone connected with agriculture or working with crops is acquainted with the fact of the existence of numerous varieties of plants. The question at once arises in one's mind as to how these different forms came into existence. The causes or reasons for the beginning of these variations or differences is a question that is perplexing to the minds of many scientists. On this question there is rather a considerable difference of opinion, Still it is proposed to explain here, how these variations have been produced.

Two remarkable tendencies, *heredity* and *variation*, are common to all organisms whether plants or animals. The first is a tendency of the offspring to resemble the parents and therefore to resemble one another. This is evidently a conservative tendency, that is one which tends to reproduce the parental characters in the offspring. Variation on the other hand, is a tendency for the offspring to be unlike their parents and therefore to be dissimilar to one another. This apparently is a progressive tendency, without which it would be impossible for new types to arise from pre-existing types. New types were probably formed with both of these tendencies in action.

One of the earliest theories which was advanced to explain this variation was expounded by Charles Darwin in his theory of "Natural Selection." According to this theory, plants and animals in nature produce many more progeny than can possibly survive. For instance, a single plant of tobacco produces at least 360,000 seeds in one generation. If all of these seeds produced offspring, in a few years' time the tobacco plants would be more than sufficient to cover the entire surface of the earth. Some other plants are even more prolific than tobacco. Naturally, this results, on account of this high production of individuals far beyond the earth's facilities to support them, a *struggle for existence.* For instance, there is great competition between different individuals in nature for food, light and water. This competition may extend to different individuals of the same type, to individuals of one type of plants and those of other types, or to individuals of one plant

type and certain animals. This struggle leads, according to this theory, to the early death of individual organisms not suited to a given environment Thus plants such as rice or the water caltrop (*singhara*) are not fitted to grow under dry conditions. Through this struggle for existence there is a natural selection which results in the *survival of the fittest* and the elimination of the unfit. In this way nature itself is instrumental in the production of certain plants which are most fitted to survive. In other words, the struggle for existence may be considered as being itself a cause of individual differences, since any continued pressure from without awakens an adaptive response in the plant or merely selects the individual which happen to vary favourably. But the individuals of a type are not exactly the same, and even the offspring of the same parents possess certain slight differences. To illustrate this point, it may be pointed out that in man also, sons of the same parents are not exactly alike.

This theory has not been universally accepted on account of a number of serious objections, detailed discussion of which lies outside the scope of this book.

Hugo de Vries, the great Dutch botanist, was of the opinion that the principal objection to Darwin's theory of Natural Selection is removed if we give up the idea that species can come into existence by natural selection through small fluctuating variations. He has suggested what is now known as the mutation theory. The principal features of this theory are :

(1) There arises suddenly from among the indivduals of a species one which differs widely in one or more characters from the rest of the group. This process is believed to take place from time to time.

(2) The new characters of these mutant individuals are inherited, in most cases.

(3) These mutations arise quite independently of fluctuating (non-heritable) variations.

(4) Mutation may take place in any direction.

(5) The mutants differ sufficiently from the rest of the members of the group to make them subject to natural selection.

(6) Consequently all mutants that are unfit will be eliminated through the process of natural selection.

The students of evolution today lay more emphasis upon small rather than large mutations, because, in nature very wide variation from the old existing types will tend to be eliminated immediately by natural selection, whereas the smaller mutations which are fitted to the environment may slowly accumulate, thus producing at first new varieties and then new sub-species and finally new species.

Selection as a Basis of Crop Improvement

Plants through variation adapt themselves to selection. In other words, variation is a primary factor in the process of selection for crop improvement. In order to carry out selection properly, one must have an understanding of the different kinds of variations and whether they are heritable or non-heritable. In general, variations are of three kinds: (1) Modifications, (2) Combinations and (3) Mutations. Modifications are variations which are not heritable. These kinds of variation may be brought about in general by external influences due to the environment in which the plants grow. These external influences may be the amount of food supply, soil moisture, and other climatic factors This type of variation is not taken into consideration for the fundamental reason that these are not inherited and therefore no useful purpose will be served. Combination of characters is usually produced when plants of two different varieties or species are crossed (*hybridized*). There may be among the offspring certain individuals which are like one parent, certain others which resemble the other parent and still others which on account of a combination of characters are in some ways, unlike either of the parents.

Mutations are sudden, and, sometimes very large, differences which now and then arise among a great number of plants. Such occurrences are rare in nature. The characters arising by mutation are heritable, except in the case of some bud mutations. Mutation is not due to characters but to changes in the nuclear substance. Many of our valuable varieties of ornamental or other economic plants have arisen through mutations. Most of the improvement made in mangoes is due to bud mutation or bud sports. However these bud

sports do not breed true and have to be propagated vegetatively by cutting or grafting.

Some of the methods used for the improvement of crops may be enumerated as follows:

1. Improvement by selection.
   (*a*) Mass selection.
   (*b*) Pure line selection.
   (*c*) Clonal selection.
2. Improvement by plant introduction and acclimatiatizon.
3. Improvement by hybridization.

1. Improvement by selection : (*a*) *Mass Selection.*—This is a method of selecting from a large field a number of plants that conform most nearly to some ideal type. Mass selection, to be of greatest value, must be continued until the limit of improvement is reached. Consequently selection must be carried on for a number of years, and seeds from these selected plants grown every year. This system has been used for cotton, maize, *jowar*, rice and cereals in general.

A modified form of mass selection which is also an improvement on it, known as compartmental selection, consists of dividing the whole filed into small plots of say, 10′ by 10′ and of selecting the best plants from each plot. This system eliminates the effect of the variability in the fertility of the soil, and therefore is more efficient.

(*b*) *Pure line selection.*—Consists in the testing of the progeny of single individul plants and is therefore sometimes known as the "progeny row" method of selection. This method is not materially different from mass selection except that fewer individuals are selected and each selected parent plant is tested separately. The most important point in pure line selection is the isolation or picking out of the best single strain. This system was followed at the Swedish seed station at

Svalof where it is known as the "Pedigree System." This system may be conveniently adopted for plants which are naturally self-fertilized, for example, wheat. If the system is used for naturally cross-fertilized plants, care should be taken that crossing does not take place. In order to prevent crossing, the heads or flowers should be covered before they open.

(c) *Clonal selection.*—This is a modified method of pure line selection which is applied to a pure line produced asexually. Improvement by this method is obtained by isolation or selection of the best clon (sometimes written clone). This method has been used in the improvement of such crops as sugar cane, sweet potatoes, pine apples and cassava.

Bud selection.—Is a form of clonal selection. This method is applied largely to selection in the improvement of fruits, such as oranges and mangoes.

2. Improvement by Introduction and Acclimatization.—This method consists in the introduction of new varieties of crop plants from other parts of the world, and of testing them under local conditions for a period of years. If the variety proves to be promising, further selection may be made.

3. Improvement by hybridization.—Improved varieties may be produced by hybridization. This is a slower process than selection and requires a more technical knowledge of the genetic principles involved in the process. Untrained men should not attempt to produce improved varieties of crops by this method. The Royal Commission on Agriculture in India made the following remark in this connection :

"Hybridization is a much slower process than selection and requires greater scientific experience and a higher level of scientific aptitude. We are however of opinion that the plant breeder in India will be well advised to adhere to the selection method until its possibilities......have been much more nearly exhausted than is at present the case and that hybridization should only be undertaken by officers, who, in addition to special training, have had the experience of Indian crops and conditions which is necessary for successful work."

However, one should not get the impression that selection is an easy process and that it does not require technical knowledge. In order that one may be a successful plant breeder, he should not only be well versed in genetic principles, but he should also be a keen observer so that plants of the most desirable characters only will be selected.

One of the *pre-requisites of a good hybridizer* is a knowledge of sex in crop plants. There are certain types of plants in which the male and female organs are located in the same flower (hermaphrodite or perfect flower), as for example, the flowers of cotton, wheat and peas. There are certain others in which the male and female parts occur in different flowers on the same plant (monœcious). Examples of this type are maize, cucumber, pumpkin and gourd. There are still others in which the sex organs occur in different flowers located on different plants (dioecious). For instance, the male flowers of papaya usually occur in one plant and the female ones in another. Dates also have the flowers of different sexes in different plants. It is interesting to note that this fact was known to Assyrians and Babylonians thousands of years ago. It is probable that the crossing of flowers and the selection of improved varieties was known in ancient times. In more recent times, Rudolph and Camerer in the seventeenth century, proved the existence of sex in higher plants. Kolreuter in 1760 crossed two species of tobacco, and obtained the first plant hybrid on record. Wiegmann carried on experiments on the genera *Pisum*, *Vicia* and *Ervum* and was successful in producing hybrids. He then pointed out the phenomenon of dominance in hybrids. But it was not until 1900 that modern genetics began to develop when Hugo de Vries, Correns and Tschermak working independently on the same kind of experiments and while in search of literature on the subject came across Mendel's paper which was published in 1866. These workers revealed Mendel's work to the scientific world. The results are now universally known as *Mendel's Laws of Inheritance.* This work is now known all over the world and the principles are made use of in hybridization.

Gregor Mendel was an Austrian monk. He conducted a large number of experiments on the hybridization of garden peas. His experiment relating to the inheritance of tallness and dwarfness in garden peas is probably the most useful for the discussion of his theories. Mendel took tall plants (6 to 7 feet tall) and dwarf plants (¾ to 1½ feet

tall) as the parents and crossed them. He observed that from the seeds obtained from this first cross, that is of the first generation, commonly designated as F_1, the plants were all tall. The dwarfed character of one of the parents used in crossing had apparently disappeared. The character of tallness expressed in these plants (hybrids) Mendel called *dominant*; and the character which became hidden from view he called *recessive*. Mendel grew plants from the seeds of this F_1 generation which were previously self-fertilized and observed that the plants of the second generation (F_2) were composed of two classes, one group of tall (dominant) plants and the other of dwarf (recessive) plants. The number of individuals in each class were in the ratio of three tall and one dwarf. In order to determine whether these plants were pure like their parents or whether they were hybrids, Mendel grew them for another generation and obtained offsprings (F_3) which showed that the dominants of the F_2 generation separated into two classes, one class breeding true for the dominant character; and the other class producing both dominants and recessives in the same ratio as in the F_2 generation, that is three dominants to one recessive. Mendel further observed that the ratio of these two classes of dominants in the F_2 generation is one pure dominant and two hybrid dominants. He thus finally observed that the F_2 progeny ratio of three dominants to one recessive is resolved into the ratio of one pure dominant: two hybrid dominants: one pure recessive. All of the characters with which Mendel worked conformed to this formula which operates as one law, in all his experiments.

Many improvements in agricultural crops have been made, some of which have been attributed solely to effects of cultivation. Methods of cultivation as such have not been of any importance in the production of improved varieties, although they may influence the yield of the crop. On the other hand the science of genetics has shown that new varieties are the results of hybridization or, of an inherent change, such as mutation. Selection from these variations has resulted in the creation of a large number of cultivated varieties some of which breed true, and in practice, are reproduced by sexual (seeds) or asexual (plant parts) means, (such as stems of sugar cane, etc.)

Much improvement has been made since the beginning of this century, in the breeding of agricultural crops for special purposes.

Much breeding work with agricultural crops has been done recently in order to combine such characters as (1) size of plants, (2) yield, (3) resistance to drought, (4) immunity to disease, (5) length of cotton fibre, (6) resistance to cold or frost, (7) chemical composition, such as oil content, (8) flavour, (9) colour, (10) strength of stem, and (11) earliness.

Even as early as 1799 Knight in England, through hybridization, was able to combine the sweet flavour found in certain peas with other desirable seed characters, and produced certain varieties which were known in the London market as Knight's Superb, British Queen, etc.

More recently (1933) Hackbarth and others with him working with tomatoes found by crossing the small fruited *Lycopersicum racemigerum* which ripens early with *Lycopersicum esculentum*, were able to produce a certain number of early-maturing plants, some of which bear good-sized fruits.

The most outstanding work in the hybridization of crop plants is, however, in connection with wheat, Marquis wheat, one of the most outstanding bread wheats of Canada and the United States of America, was the result of crossing Red Fife (male) and an early ripening Indian wheat commercially known as Hard Red Calcutta (female). The cross was made in 1892, but the particular selection later to be known as Marquis was made by the cerealist of the Dominion of Canada, Dr. C. E. Saunders, in 1904. This selection was particularly suitable for areas that are seriously subjected to frost. In yield also it was found that Marquis exceeded Red Fife, the standard variety of that region up to that time, by about 35 to 40 per cent. The seed of this variety was distributed to the public in 1909. And up till very recent years this was the standard variety of wheat in Canada as well as in the United States of America.

In India considerable hybridization work has been done in connection with the wheat crop. Pusa 4 and Pusa 6 wheats had been selected for high yield. But these two varieties were awnless and therefore were more susceptible to damage by birds. This was a serious defect from the farmers' view point. Hence, in order to produce a high yielding strain which also possesses awns, a search was made for suitable material. Punjab 9, a bearded type, was selected

as the material for crossing with Pusa 6, a high-yielding, and rust resistant variety. As a result of this cross Pusa 52 was developed. This new variety possesses the desired combination of characters of being bearded, rust-resistant and high yielding.

The improvement of the linseed crop in India has been done mainly by the method of selection. The high quantity of oil present in the seed is the character on which much of the value of linseed depends. It was found that the Indian linseed crop is mainly composed of two types which are respectively called the "Peninsular" and the "Alluvium" types In order to produce a strain possessing the above desirable character, a search is being made among these two types so that certain desirable characters of these types may be combined. Up to the present two high yielding types, Type No. 12, white-flowered, and Type No. 121, purple-flowered, which exceed the local varieties in yield by 40 to 50 per cent, have been selected. The oil content of Type No. 12 varies from 37·96 to 39·39 per cent; whereas that of Type No. 121 varies from 41·07 to 42·65 per cent. The latter type is also said to possess a high degree of resistance to linseed wilt.

The work for the improvement of the sugarcane crop in India really began in 1912 with the opening of the cane breeding station at Coimbatore, with Dr. Barber in charge of the work. He introduced the wild species, *Saccharum spontaneum*, into the parentage of cross-bred canes. The type Co. 205 is the product of the direct cross between wild species and a Noble cane, a thick type generally grown in northern India. This variety is one of the popular canes of the Coimbatore series. Among other popular improved types are Co. 214, Co. 210, Co. 213, Co. 285, Co. 290, Co. 313, and Co. 357. The success of the work in the improvement of the sugarcane crop may be evaluated according to the Indian Tariff Board Report, 1931, where it is mentioned that 877,000 acres are planted with Coimbatore seedling canes. The main sugar tract, the United Provinces and Bihar, has a total sugarcane acreage of 1,644, 000 acres, out of which 700,000 acres are planted to Coimbatore seedling canes. Coimbatore canes are now not confined only to India, but have spread to many of the sugarcane growing countries throughout the world.

More recently the workers at Coimbatore have succeeded in hybridizing sugarcane and sorghum (*jowar*). In this way they were

able to shorten the period of growth and thereby, can grow some other quick-maturing crops in the same field the same year. This production of sugarcane-sorghum crosses is undoubtedly a great achievement. However its practical possibilities are yet to be determined.

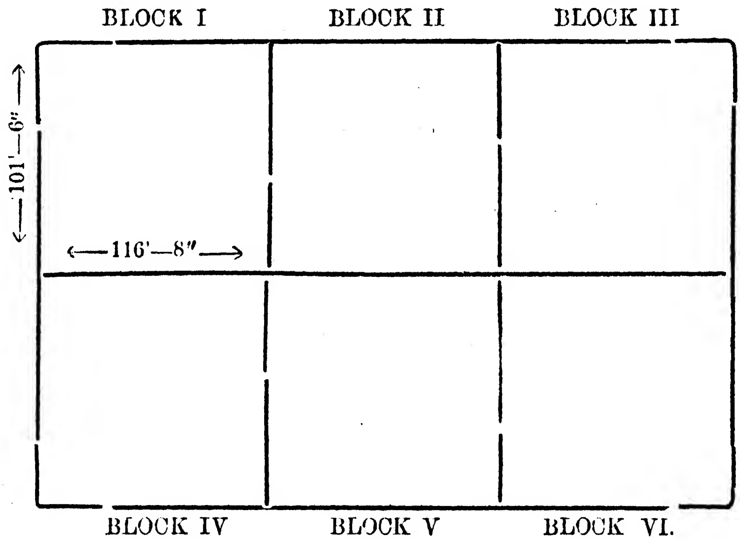
The Use of Statistical Methods in Crop Improvement.

The use of statistical analysis in crop improvement is comparatively recent introduction into this country, and its adoption has greatly improved the technique and accuracy of field experiments. While statistical methods had been used for a long time in agricultural experiments by some workers, but the development of the present day statistical methods is largely due to R. A. Fisher. These methods are now being increasingly used in India, so much so, that it becomes very necessary for a student of agriculture to be able to understand not only the laying out of field experiments, on the model of Fisher's Randomized Blocks and Latin Squres, but also the statistical analysis of the results.

One of the main reasons these methods should be used is because they enable one to decide, more or less accurately, whether the differences or variations between different treatments, or, between different varieties of crops, are "significant", that is, large enough to be considered as real differences. The use of these methods constitutes a distinct improvement over the old method, in which the plots of different treatments or varieties are arranged systematically, with control plots at frequent intervals in the experiment. The difficulty with this old method was in correctly interpreting the yield data, as the differences in the yield of crops are influenced by soil fertility differences, by the effect of particular seasons on the different treatments under comparison, and by certain interacting factors such as errors of measurements, incidence of disease, insect attacks and the like.

In order to make the discussion on this subject clear it is desirable at this place to give a concrete example of a modern randomized experiment. In the experiment there were ten different varieties of *jowar* to be tested and whose yields were to be compared with one another. Let those varieties be represented by the letters A, B, C, D, E, F, G, H, J and K. (*N. B.* The letter I is not generally used as it may sometimes be taken for L, 1 or something else).

It was decided to have six replications or repetitions of these varieties. The experiment therefore contained 6 blocks and 10 plots in each block. That is, each variety occupied one plot in each block; and as there were six blocks, the total number of plots was 6×10 or 60. In this experiment the distance between rows was 14 inches. The rows in each plot were ten in number and the length of these rows was 93′ 6″. In the experiment two rows, one on each side of the plot and four feet on each end of the plot were considered as border rows, that is non experimental material, in order to eliminate the margin effect. Besides these non-experimental rows between plots there were four rows on each side of the whole layout which also were guard rows. The form of the layout was therefore as follows:—



Area of the layout = 101′·6″ × 700′ = 71050 sq ft.

The size of an experimental plot in this experiment was therefore 93′ 6″ × 9′ 4″. It should be noted that the size of each block was 101′ 6″ × 116′ 8″, and was therefore almost a square in shape. In order to facilitate the carrying out of this experiment, it was desirable to have a well-made plan of the layout as given above. When this was completed the next step was to allot the different varieties to different plots in the block. This was done by randomization, that is, by chance allotment. This was done by writing the names of the varieties, A,B,C,D, etc., on slips of paper or card-board and after mixing or shuffling them thoroughly they were placed in a hat and then

drawn or picked out at random. The variety that was picked out first was automatically alloted to plot No. 1 in the first block, the variety that was picked out next was alloted to plot No. 2 of the some block. This process was repeated until the allotment of all the varieties in the first block was completed. This procedure was repeated for each of the remaining blocks until the allotment for the whole layout was complete. The result of this randomization in this particular experiment was as given below.

BLOCK I	BLOCK II	BLOCK III
G B A E F J K C H D	C H D F E G B A J K	H K E J D G B C A F
C A H G D K E F J B	H J A C F D B K E G	G J E K A C D F H B
BLOCK IV	BLOCK V	BLOCK VI

When the crop was mature the heads were harvested and threshed and the yield of grain of the different varieties from different plots was weighed and recorded. The yields thus obtained were as shown in the table below.

For purposes of calculation, the yield in lbs. was arranged as given below :

TABLE XII

Showing the yield of grain in lbs. of different varieties in different plots.

BLOCKS.

Varieties.	1	2	3	4	5	6	Total	Mean.
A ..	28 5	30·5	27·9	28 3	32 4	24 4	172 0	28·7
B	32·4	39·6	33 3	29 7	37 0	32·0	204 0	34 0
C	26·7	27 0	25·6	30·6	29·4	29 2	168 5	28·1
D ..	23·0	28·0	27·0	27·5	26 9	24 9	157·3	26·2
E	23·5	30 5	26·7	27 5	26·8	32 2	167·1	27·8
F	26·7	27·7	27·0	22 6	23 1	26·7	153 8	25·6
G	27 5	33 5	27·4	31·5	29·5	18 9	168 3	28 0
H	27·6	30 0	25·9	25 0	28·7	27·1	164·6	27 4
J	34·7	30 8	26·3	25 0	31 4	29 7	167 9	28 0
K	28·7	29·6	24·5	26 0	28·7	27·0	164 5	27·4
Total ..	269·3	307·2	271·6	273 6	293 9	272 4	1,688 0	28 1

After the figures had been tabulated the variety totals and the block totals was calculated. These were obtained by adding the figures in the rows and columns respectively.

In order to further analyse the results three different methods are generally followed. But only one method which is generally easier to understand is followed here; although for arriving at the results the two other methods, which are not explained in this book, are more commonly adopted.

The first step in this process was to determine the mean per plot. In the above experiment the grand total which was 1688·0 was divided by 60 which is the total number of plots in the entire experiment. The mean yield of 28·1 was thus obtained.

This was then subtracted from each *variate* which was the yield from each plot in order to obtain the deviation from the mean. These deviations may be positive or negative and the signs should be shown. The deviations thus obtained are shown in table No 13.

TABLE XIII

Showing the Deviations.

BLOCKS

Varieties.	1	2	3	4	5	6
A	+0·4	+2·4	−0·2	+0·2	+4·3	−3 7
B	+4·3	+11·5	+5·2	+1·6	+8·9	+3·9
C	−1·4	−1·1	−2·5	+2 5	+1·3	+1·1
D	−5·1	−0 1	−1·1	−0·6	−1·2	−3·2
E	−4·6	+2·4	−1·4	−0·7	−1·3	+4·1
F	−1·4	−0·4	−1·1	−5·5	−5·0	−1·4
G	−0·6	+5·4	−0·7	+3·4	+1·4	−9·2
H	−0·5	+1·9	−2·2	−3·1	+0·6	−0·6
J	−3·4	+2·7	−1·8	−3·1	+3 3	+1·6
K	+0·6	+1·5	−3·6	−2 1	+0·6	−1·1

These deviations were squared, and then added to obtain what is called the sum of squared deviations generally known as *sum of squares*. The squared deviations and their total, for the sake of clearness, are shown in table No. 14. Thus the figure 693·09 is the sum total of the squared deviations.

Table XIV

Showing the Squared Deviations.

BLOCKS

Varieties.	1	2	3	4	5	6	Total.
A	0·16	5·76	·04	0·04	18·49	13·69	38·18
B	18·49	132·25	27·04	2·56	79·21	15·21	274·76
C	1·96	1·21	6·25	6·25	1·69	1·21	18·57
D	26·01	0·01	1·21	0·36	1·44	10·24	39·27
E	21·16	5·76	1·96	0·49	1·69	16·31	47·87
F	1·96	0·16	1·21	30·25	25·00	1·96	60·54
G	0·36	29·16	0·49	11·56	1·96	84·64	128·17
H	0·25	3·61	4·84	9·61	0·36	0·36	19·03
J	11·56	7·29	3·24	9·61	10·89	2·56	45·15
K	0·36	2·25	12·96	4·41	0·36	1·21	21·55
Total ..	82·27	187·46	59·24	75·14	141·09	147·89	693·09

The next step in the process was to find out the sum of the squared deviations due to blocks and that due to varieties. This was found out by first finding the mean yield per block and the mean yield per variety respectively. The mean yield per block was obtained by dividing the total yield by the number of blocks. Thus the mean yield per block was $\frac{1688{\cdot}0}{6} = 281{\cdot}38$, and the mean yields per variety was $\frac{1688{\cdot}0}{10} = 168{\cdot}8$. The deviations of the block yield were then obtained by subtracting the yield of the block from the mean yield per block. The deviations were then squared and added as follows:

TABLE XV

Showing the deviations and the squared deviations of block yields.

Block.	Actual Yield—Mean Yield.	Deviations.	$(\text{Deviations})^2$
1	269·3 – 281·33	– 12·03	144·7209
2	307·2 – 281 33	+25·87	669·2569
3	271·6 – 281 33	– 9 73	94·6729
4	273·6 – 281 33	– 7·73	59·7529
5	293·9 – 281·33	+12·57	158·0049
6	272·4 – 281·33	– 8·93	79.7449
	Total 1688 0—1688 0	0	1206.1534

The figure 1206 obtained in table No. 15 and which was the total of the squared deviations due to blocks was then divided by 10 which was the number of plots per block in order to get the deviation per plot. Thus 1206 ÷ 10 = 120·6 was the "sum of squares" due to blocks.

The sum of squares due to varieties was also obtained in a similar way as shown in table No. 16. Only in this case, it should be noted, from the variety yields was subtracted the mean yield per variety which, as indicated above, was 168·8.

TABLE XVI

Showing the deviations and squared deviations of the yields of each variety.

Varieties.	Actual yield—Mean yield.	Deviations.	$(\text{Deviations})^2$.
A ..	172·0 – 168·8	+ 3·2	10·24
B ..	204·0 – 168·8	+35 2	1239·04
C ..	168·5 – 168.8	– 0·3	0 09
D ..	157·3 – 168 8	– 11·5	132·25
E ..	167·1 – 168 8	– 1·7	2·89
F ..	153·8 – 168 8	– 15·0	225·00
G ..	168·3 – 168·8	– 0 5	·25
H ..	164·6 – 168 8	– 4·2	17·64
J ..	167·9 – 168 8	– 0·9	·81
K ..	164·5 – 168·8	– 4·3	18·49
Total ..	1688·0 – 1688·0	0	1647·70

The figure 1647·7 which was the total of the squared deviations due to varieties was then divided by 6, which was the number of plots per variety. The figure 274·4 thus obtained was the "sum of squares" due to varieties. The next step in the process was to add the sum of squares due to blocks and varieties which was 120·6 plus 274·4 or 395·0. This total was then subtracted from the 693·09 which was the total sum of squares. The remainder which was 298·09 was then regarded as the sum of squares due to error. Thus the total sum of squares which was 693·09 had been analysed into three groups of sums of squares, that is the sum of squares due to blocks, to varieties and to error. These three sums of squares were then divided by what are called the degrees of freedom, the divisors being in the case of blocks, the number of blocks in the experiment less one, in the case of varieties also the number of varieties less one, and in the case of error sum of squares, it is the total number of degrees of freedom or the total number of variables or plots in the experiment less one minus the sum of the degrees of freedom due to blocks, and that due to varieties. Thus in this experiment there were $6-1$ or 5 degrees of freedom due to blocks, $10-1$ or 9 degrees of freedom due to varieties, and $(60-1)-(5+9)$ or $59-14$ or 45 degrees of freedom due to error. Dividing the different sums of squares by these respective degrees of freedom the mean square or variance for each one was obtained. The results are put in a tabular form as follows :

TABLE XVII

Analysis of Variance.

Due to	Degrees of freedom.	Sum of Squares.	Mean Square.
Blocks ..	5	120·60	24·15
Treatments ..	9	274·40	30·49
Error ..	45	298·09	6·62

The next step in the process was to determine whether the difference was due to errors or random sampling or to the direct effects of the varieties or of the treatments applied. This was determined by a

method which, is known as a Z – test or test of significance, a method developed by R. A Fisher. The value of Z is determined by the formula.

$$Z = \frac{1}{2} \text{ loge } (S_1^2/S_2^2)$$
$$= \frac{1}{2} (\text{loge } S_1^2 - \text{loge} S_2^2)$$

Thus in this experiment Z was determined as follows :

TABLE XVIII

Analysis of Variance.—(Contd).

Due to.	Degrees of freedom.	Sum of squares.	Mean square or variance.	Log 10 of Mean Square.	Log 10 × 1·1513 or ½ Loge.	Z	Level of significance.
Blocks ..	5	120·60	24·15	1·3829	1·5921	·6471	1%
Treatments ..	9	274·40	30 49	1 4842	1·7087	·7637	1%
Error ..	45	298 09	6 62	0·8209	0·9450	..	..

Thus as shown in the above table the figures in the fifth column were obtained from a logarithm table. The figures in the next column were obtained by mutiplying log 10 of the mean square by 1·1513. In this way ½ loge S^2 given in the above formula was obtained. The value of Z is the difference of the different values of ½ loge S^2. In Z – tables in R. A. Fisher's book entitled "Statistical Methods for Research Workers", the following values of Z are found for the 1 and 5 per cent. probabilities opposite the degrees of freedom designated here as N_1 and N_2 where N_1 represents the number of degress of freedom of a higher mean square and N_2 of a lower mean squre. For this experiment it was found that the tables do not have the values for N_2 at N45 and therefore the values at 30 and 60 are given thus:

N_1	N_2	Z1%	Z5%
5	45	·6540 to ·6028	·4648 to ·4311
9	45	·5773 to ·4574	·4090 to ·3255

It will be seen that the figures, in table No. XVIII both due to blocks as well as to varieties show a significance at 1 per cent level.

The next step in the statistical analysis of the results was to calculate the standard error. Its arithmetical value is obtained by dividing the standard deviation of any variable by the square root of the number of variables in the sample, or stated briefly,

$$\text{Standard Error} = \frac{\sqrt{\text{Mean square or Variance}}}{\sqrt{n}} = \frac{\sigma}{\sqrt{n}}$$

In this experiment the standard error was found by dividing the square root of the variance due to error by the square root of the number of plots per treatment as follows:

$$\text{S. E.} = \frac{\sqrt{6{\cdot}62}}{\sqrt{6}} = \frac{2{\cdot}57}{2{\cdot}45} \text{ or } 1{\cdot}05.$$

The standard error of difference between any two treatments is obtained by multiplying the standard error by $\sqrt{2}$ or 1·4143. Thus in this experiment the standard error of difference between treatments was $1{\cdot}05 \times 1{\cdot}4143 = 1{\cdot}4850$.

By referring to the t table in R A. Fisher's book, it was found that the value of t for a 5% probability and 45 degrees of freedom is about 2. This figure is used to multiply the standard error of difference between two treatments in order to get the significant difference between any two treatments. This is therefore, $1{\cdot}4850 \times 2$ or 2·97.

The mean yields of the different varieties as shown in table No. XII and arranged in a descending order of yields are as follows:

B	A	C	G	J	E	H	K	D	F
34·0	28·7	28·1	28·0	28·0	27·8	27·4	27·4	26·2	25·6

In order to find out whether these varieties are significantly different from one another, one has to see whether the differences in yields between the varieties are greater or less than 2·97. Where this difference was less than 2 97 the line was drawn to group those varieties together as shown above.

Thus this experiment indicated that the variety B was significantly higher in yield than all the others. Likewise the variety A, was significantly superior to F, but not significantly different from C, G, J,

E, H, K, and D. Finally C, G, J, E, H, K, D, and F were not significantly different from one another.

It may be pointed out that the standard error in this experiment was 1·05 where the mean yield of a plot was 28·1. In other words words the standard error was $\frac{1.05+100}{28\ 1}$ or 3·7 per cent. This standard error percentage is sometimes known as the coefficient of variability and indicates to a large extent the degree of efficiency with which the experiment had been conducted.

Fundamental Considerations in the Laying out of Modern Field Experiments

The fundamental considerations in the laying out of field experiments are the following :

1. **The site.**—That is the place where the experiments are to be laid out, should be representative of the soil in the area where the crop is to be grown commercially, and should be as uniform as possible, to reduce the effects of differences in soil fertility between plots. The uniformity in soil fertility of a field may be estimated by carefully noting the growth of the previous crop.

2. **Replication.**—Or the process of repeating plots of the same treatment, is very essential. The number of replications should never be less than five in order to obtain accurate and conclusive results, and may vary from six to ten. The objects of replication, stated in the words of R. A. Fisher, are two-fold : (1) to diminish the errors to which the field errors are subject.........and (2) to supply an estimate of error, and this is a purpose which can be attained by no other means. That is, the object of replication is to average out experimental errors and to secure through the mean a better indication of the performance of the treatment than any single plot could provide, and also to secure the data from which an estimate of error could be determined.

3. **Randomization.**—Which means, subject to certain restrictions, the random arrangement of any one treatment or variety is also essential in the process because the estimate of error in an experiment of this kind can only be found when each set of plots is truly a ran-

dom sample from the area covered by the experiment. This is necessary because the formula for the standard error $\frac{6}{\sqrt{p}}$ (where *6* is the variance and p the number of variables in the sample) can only be used when the treatments or varieties are randomized. This formula is only in accordance with the law of chance.

4. **Local control** is the principle made use of in these experiments by imposing certain restrictions in the random arrangement of treatments or varieties in order to eliminate portions of the total variance which are irrelevant in the making of comparisons. In the comparisons of certain treatments or varieties there is a considerable amount of error introduced into the experiment due to soil heterogeneity or differences in soil fertility from one part of the field to another. A reduction in the variation or error in the experiment due to soil heterogeneity is brought about by the system of randomized block arrangements. By this method the variation due to blocks is removed and thus there is a consequent reduction in the error of the experiment, and thus its accuracy is increased.

5. **Size and shape of plot.**—While it is difficult to give a particular size or shape of plot to be used under all circumstances, yet it has been found that the most suitable size for most field crops is 1/40 acre. But smaller plots may be used with a higher number of replications. The shape of the plot may vary from square to rectangular, but the narrow and long plots are considered more desirable under most conditions.

In case there is likely to be a border effect, then one or two guard rows on the side of each plot are desirable in order to eliminate any such effects from the yield records.

6. **Cultural treatment.**—That is all plots should have uniform treatment. Care should also be taken to get a fairly uniform stand. In order to ensure this, more seed may be planted and the plants thinned after germination.

This is desirable, as a comparison of treatment yields is unfair unless the number of plants in the plots is more or less the same.

7. **Observations.**—In carrying out an experiment statistically, it is not only the final yields that matter, but sometimes observations

of the rate of growth, vigour, attacks of pests and diseases, etc., are very valuable. Hence weekly or more frequent visits are desirable. Such observations as are made during these visits should be entered in a field note-book for future reference.

8. Although the method of statistical analysis on the whole remains the same in principle, yet the value of particular experiments depends largely on the *type of layout* and the *appropriate method of statistical analysis* employed in the interpretation of the results. The example given above constitutes probably one of the simplest types of designs, and allows an easy interpretation of the statistical analysis involved in such experiments.

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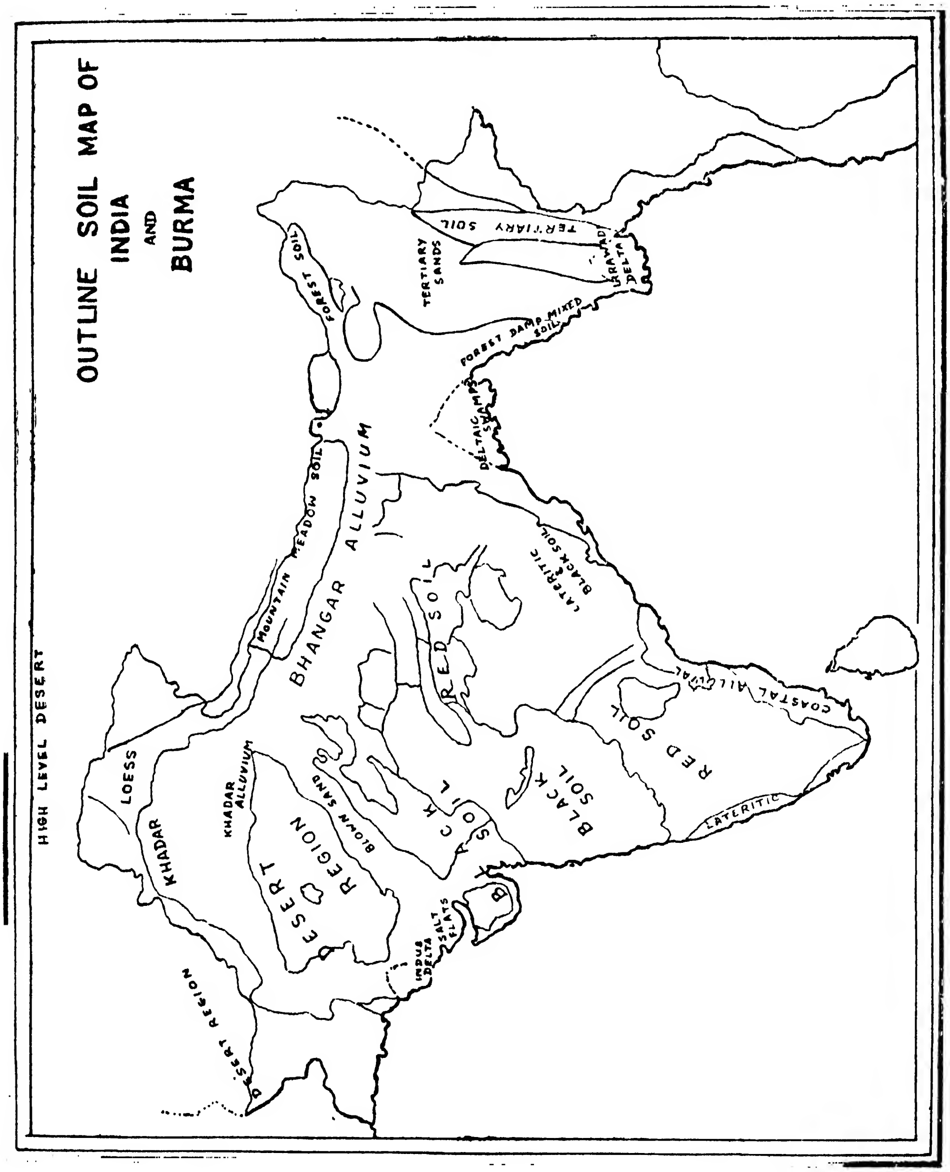

The soil map of India and Burma.

(Adapted from the Soil map by D. N. Wadia and others)

CHAPTER VI

The Soils of India.

The character of the agriculture of a country is dependent to a large extent on the nature and properties of its soils and its climate. The nature and character of soils is again greatly dependent upon the climate of the region in which the soil occurs. Because of this fact soils of this country which extends from the temperate regions through the sub-tropical and into the torrid zone therefore vary considerably. The development of the scientific study of soils has taken place almost entirely in the temperate regions. But in recent years the study has been extended to the tropical and sub-tropical soils. Hilgard, Ramann and Glinka were among the first to point out that the climatic agencies of the locality in which the soil occurs and the parent rock, are jointly responsible for the formation and distribution of different types of soils. Mohr and Pendleton working in the Dutch East Indies and China, in recent years, have also expressed a similar opinion, regarding the importance of climate in soil formation.

While the same climatic agencies are at work in both temperate and tropical regions, yet there is a material difference in the effects of weathering in the two regions. This difference is due mostly to the degrees of intensity of climatic action, as well as to the length of duration of the action of climatic factors, since there is, in the tropics, no winter to interfere with these intense soil-forming processes. Vageler claims that since the temperature is 10° to 20° C. higher in the tropics than in temperate regions, all chemical reactions proceed at from twice to four times the speed usually taking place in temperate climates. He further claims that the changes effected by rainfall are in some cases, 20 to 30 times greater in the humid tropics, than in the temperate zones.

Another influence of climate on the soil is shown clearly by the humus colouration which is lacking in many tropical soils. But, to conclude that the humus content of tropical soils is low is incorrect as the presence of iron and sometimes of manganese compounds may mask the colour due to humus. The larger portion of the humic

substance in the tropical regions is usually colourless or only faintly coloured and usually blackens easily when exposed to air. It is easily decomposed, and therefore the water-soluble constituents of the decomposing plant materials are quickly absorbed in the soil. When the original plant material is low in calcium, the soil formed in the presence of the humus from such material is more often clayey or of a clayey and loamy texture. The loams are usually bleached and usually become light yellow in colour. This mistaken idea that humus is practically absent from tropical soils has led some people to believe that clean cultivation cannot destroy the humus. However, the humus content in tropical regions is not always high and the soil could therefore be considerably improved by the addition of organic matter, as has been shown by numerous experiments in the Dutch East Indies as well as in this country.

The researches of Mohr have shown that the soil colloids are formed continuously and more rapidly in the tropical regions, as residues of decomposition or by actual synthesis; and that these release large quantities of plant food which are further increased by tillage. This is an important factor to consider in the evaluation of tropical soils. That is, farming operations affect the decomposition of soil materials to a very marked degree in tropical soils as compared with soils of temperate regions.

Natural vegetation is another very important factor influencing the nature and properties of soils, due to the fact that the nature of the humus is dependent upon the character of the plants from which it is derived. For example, the peat soils of the temperate zone known as the Sphagnum peats are very different in composition from those found in the tropics. These peaty soils are more common in the tropics than they are usually supposed to be. These peaty soils in India are exemplified by the forest peats in humid regions like Travancore in the Southwest, and Assam in the Northeast of India and by the peaty soils of swamps and *jhils* or by the peaty layers of soil which occur as intercalations in the loams or silts of the river deltas.

Mohr, as a result of his researches in the Dutch East Indies, divided the soils into three groups based more or less on the influence of the climatic factors on the soils, especially the influence of rainfall and evaporation.

The first group comprises of soils in regions where rainfall exceeds evaporation throughout the year, that is in humid regions. In the soils of these regions percolation is very active and results in the dissolution of soluble mineral and organic materials leached into rivers and ultimately into the sea, leaving the soil in an impoverished condition unless fertilizing constituents are again supplied from other sources.

The second group comprises the soils in regions where evaporation exceeds rainfall throughout the year. This condition is found in arid regions. In the soils of these regions the water which falls in the form of rain is not sufficient to percolate downwards to any great depth and after a time returns upward and is lost by evaporation. The solution passing upwards contains many dissolved mineral substances, which on evaporation are left on the surface of the soil. This process therefore enriches the surface soil, but if the deposition of salts on the surface soil is very great, the soil becomes unproductive and such soils are called "usar" in India. It may be of interest to note that some of the great agricultural civilizations of the past were developed in regions in which *usar* has since developed.

The third group comprises soils in regions where there is an alternation of wet and dry seasons. In such regions the rainfall is usually slight compared with the torrid zone and the temperature is also low, so that there is very little downward and upward movement of soil materials.

According to this classification the soils of India would fall into all the three groups. The soils of Travancore, Assam, some portions of the Western Ghats, Bengal, Bihar and the southern slopes of the Himalayas including the *terai* soils, fall under the first group.

The second group of soils will be found in Rajputana, Sind, Kathiawar, the western Punjab and some parts of the United Provinces, especially the districts of Meerut and Aligarh.

The third group of soils would perhaps be represented in India by soils of the eastern Punjab, the south-eastern United Provinces, Madras, Bombay, the Central Provinces and Central India, in which there is more or less of a balance between the upward and downward movement of soil materials. The placing of the above soils in these groups is somewhat difficult, as there is no definite line of demarcation and as

they gradually merge from one group into another. Most soils in temperate regions fall into the third group.

With the above preliminary and general introduction, the soils found in different parts of India will now be discussed. There is a great lack of detailed information regarding the soils of India and therefore only a very general survey can be given.

The soils of India have been investigated to some extent by the geological survey of India. J. W. Leather and more recently D. N. Wadia and others have made further notable contributions towards our knowledge of the soil types of India. As a result of their work four main soil types have been recognized in India. These four types are: (1) The Indo-Gangetic alluvium including that brought down by the Brahmaputra, (2) the *regur* or "black cotton soils" which overlie the Deccan trap, (3) the red soils derived from the rock of the Archaean system and commonly found in Madras and Mysore, and (4) the laterite soils which form a belt around the peninsula extending through East Bengal into Assam.

THE ALLUVIAL SOILS

This type of soil is by far the most extensive and agriculturally the most important of all the soil groups in India. This soil is usually referred to as the Indo-Gangetic alluvium as the greatest portion of this soil is found in that region. But these alluvial soils are also found in the Brahmaputra valley, the Surma valley in the south of Assam, and in the valleys of the Godavari, Kistna and the Cauvery. These soils cover an area of about 300,000 square miles. They are found in the greater part of Sind, the northern part of Rajputana, the greater part of the Punjab, the United Provinces, Bihar and Bengal, and about half of Assam. These soils are derived mainly from the Himalayas having been brought down by the three great river systems of northern India, the Indus, the Ganges and the Brahmaputra. These rivers bring down the soil materials and deposit them in the plains below. The maximum thickness of these deposits has not been found out, but some borings indicate that the depth exceeds 3,000 feet. The soils of this group differ according to their local origin and vary in texture and physical consistency from sand through loams and fine silts to stiff

heavy clays that entirely prevent drainage, sometimes resulting in the accumulation of injurious salts, producing a sterile condition commonly known as *usar*. The accumulated salts are largely those of sodium and magnesium.

The chemical analysis of these soils shows that in general they are low in nitrogen and organic matter, that the amount of potash is adequate, and phosphoric acid though adequate, is usually less than in other Indian soils. The lime content of these soils shows a great variation. For example in the Tirhut district of Bihar, the soil often contains over thirty per cent of carbonate of lime, whereas the soils of the adjoining districts are completely lacking in lime. However, the amount present may be generally considered sufficient. The Indo-Gangetic plain represents the drainage of the southern slope of the Himalayas, whereas the Brahmaputra valley represents the drainage of the northern slope. The Brahmaputra represents a region of very heavy rainfall, and southern Assam a region of highest rainfall known. Consequently the soils brought down by the Brahmaputra are to a large extent leached of their soluble salts. A comparison of the chemical composition of the alluvial soils of these two regions indicates that the soil of the Brahmaputra contain an extremely low percentage of lime; ·08 per cent is a general average as against 1 per cent for the Indo-Gangetic soils. In the latter soils potash ranges between ·65 and ·70 per cent while the Brahmaputra soils in Assam contain from ·25 to ·35 per cent. Magnesia averages about 1·30 per cent against ·50 per cent in the Indo-Gangetic and Brahmaputra soils respectively. These figures indicate considerable leaching in the Brahmaputra soils, as the result of rainfall.

Another important characteristic of the Indo-Gangetic alluvium is the formation of nodular calcareous material known as *kankar*. This material is formed at a depth of a few feet below the surface of the soil, sometimes forming an impervious layer of what is known as "hard pan". Such layers occur very generally in the United Provinces and also in Bengal and parts of the Punjab.

These alluvial soils of the Indo-Gangetic plain are also characterised by ease of cultivation and rapid response to irrigation and manuring. Generally speaking, there are few soils in the world which are more

suited to intensive cultivation of crops, so long as the water supply is adequate.

In the Punjab, the Indo-Gangetic alluvium extends westwards as far as Lahore. From Lahore westwards for some distance, the Indo-Gangetic alluvium is overlaid by wind-borne soil (*loess*). Beyond this loess area the Indo-Gangetic alluvium again occurs. The Indo-Gangetic alluvium as far as Lahore, is within the influence of the southwest monsoon and is benefited by it, whereas the area west of Lahore is not subject to a regular and systematic rainfall in the monsoon season, although there is a general increase in the amount of rain from Sind towards Lahore where the annual rainfall is about 15 inches. The rainfall continues increasing eastward, amounting to about 25 inches in the eastern Punjab and to about 70 inches in Bengal. The region west of Lahore presents physical characteristics differing in many ways from those of the Indo-Gangetic alluvium to the east. In the western tracts the climate is hot and dry, whereas, as one travels eastward, the climate is characterised by a greater amount of rain and humidity during the monsoon. Thus the entire area of the Indo-Gangetic alluvium may be divided into four fairly distinct regions on the basis of rainfall, the first extending from Lahore to Delhi with an annual rainfall varying approximately from 15 to 25 inches, the second area extending from Delhi to the eastern border of the United Provinces with an annual rainfall varying from about 25 to 40 inches, the third extending from the eastern border of the United Provinces to the east of Bihar with a rainfall of 40 to 55 inches and the fourth area extending from Bihar to the Bay of Bengal where the annual rainfall varies from about 55 to 70 inches, and where the humidity is also very high almost throughout the year.

The types of alluvial soils that are most predominant in the **Punjab area** are the loams and sandy loams interspersed with patches of clay especially in the western portions of the Lahore district. In Jullundur, loams, sandy loams with patches of clay predominate. In these soils are also found patches of *kankar*. In the southern portion of this area, comprising of the districts of Ferozepore and Hissar and Patiala State, loams with patches of clay are fairly common with the sandy loams predominating. The outstanding characteristic of the soils of these districts is the shifting sand dunes. The soils in the

eastern portion of the Punjab comprising the districts of Ambala, Karnal and Rohtak are very variable in character, ranging from fertile loams to heavy clays.

Results of experiments conducted in the Punjab have shown that the alluvial soils of this region possess the following chemical characteristics. (1) It has been found that these soils are capable of fixing nitrogen very rapidly. (2) The nitrogen content of the Punjab soils varies from 0·025 per cent. to 0·100 per cent. This when compared with the nitrogen content of European and North American soils, indicates that the Punjab soils are poor in nitrogen. (3) It has been found that in general the Punjab soils are not deficient in potash, the average of the analyses made, being 0·72 per cent. (4) The phosphoric acid content of the Punjab soils has been found to vary on the average from 0·1 to 0·3 per cent. These figures show that in general the alluvial soils of the Punjab may be considered to contain a sufficient amount of phosphorus. (5) The lime content of the Punjab soils is very variable, but there appears to be a tendency for the lime content to increase progressively from the Himalayas to the southwest. (6) The alluvial soils of the Punjab are on the whole deficient in organic matter, most of them containing on an average from 2 to 4 per cent. of organic matter.

In the **United Provinces area,** approximately 53·776 square miles are included in the Indo-Gangetic alluvium. The soils of this area, while appearing to be uniform, really vary considerably from drifted and blown sand through loams, and silts to very heavy clays.

These soils have been brought down mainly from the Himalayas, and the many physical differences that are found in these soils depend mostly on the sorting action of water, the deposits varying largely with the velocity of the water.

Chemically, these soils have been found to contain sufficient quantities of lime, potash and phosphoric acid, but the amount of nitrogen when compared with the soils of western countries is low. But it would appear from various experiments conducted in this country that these soils can renew their supply of nitrogen much more rapidly than those of the colder European countries.

In general the alluvial soils of this area will be found to have a tendency to become progressively heavier as one proceeds from the

northwest to the southeast portion of the area. This is probably due to the fact that the rivers deposit heavier materials first and lighter materials farther down when the velocity of the water is decreased, or it may be due to the fact that the amount of rainfall in the eastern regions is greater than in the west of this area.

The soils of this area sometimes contain sub-soil layers of nodular limestones or *kankar* at a depth of a few feet from the surface.

In the northwest area where the conditions are semi-arid, patches of alkali soils frequently occur, especially in the districts of Meerut, Aligarh, Muttra, Agra and Partabgarh.

The alluvial soils of this area are of considerable depth. Borings made at Lucknow to a depth of 1336 feet indicate the great thickness of these alluvial deposits.

On the whole, these soils possess a loose sub-soil, usually made up of different layers of soils material of varying texture.

In the **Bihar area,** most of the Indo-Gangetic alluvium lies on the northern side of the Ganges where the land slopes gradually from the Himalayas towards the south where a belt of fairly high land occurs, which is being continually built up by the flooding of the Ganges. Between these two extremes the general elevation is lower and consequently considerable areas are liable to damage by floods. The soil consists mainly of the older alluvium known as *bhangar*, a yellowish clay with frequent deposits of *kankar*. This type of soil extends up into the northeast corner of the United Provinces. But in many parts the soil of this area has been cut away by the torrents that rush down from the Himalayas through the lowlands which these rivers have had to pass before they join the Ganges, and in its place more recent deposits of sand and silt have been laid down, which were brought down by them when in flood.

In general the alluvial soil of this tract contains a sufficient amount of lime and potash, but is somewhat lacking in phosphoric acid, and quite low in the amount of nitrogen and organic matter.

In the **Bengal area** the Brahmaputra joins the Ganges, and consequently the alluvial soils brought down by these two rivers are found. Here the amount of rainfall is greater than in the "Bihar area". Therefore the character of the soil is greatly

influenced by the climatic factors prevailing in this area, and also by the fact that the rivers have become somewhat sluggish. The finer material that is deposited all over Bengal consists of fine silt along the banks, and clay a little distance from the banks of the rivers. The soil of this area may be classed as either old alluvium or new alluvium, the former being found for the most part to the west and the latter to the east of a line running north and south approximately a little to the west of Calcutta and Darjeeling. The recent alluvium is periodically fertilized by fresh deposits of silt from the overflowing rivers. Usually at the deltas the soils are found in layers with peat and other organic matter.

The topography of the new and the old alluviums are somewhat different in that the latter is in the process of being denuded while the former is in the process of formation or building up. The surface of the new alluvium is therefore more or less a level plain, whereas that of the older alluvium has become undulating due to the scouring action of the rivers. Recent alluvial deposits with the exception of strips of high lands along the banks of the rivers, make the whole country low and swampy.

This alluvium extends eastward into the Brahmaputra and Surma Valleys in Assam. The Brahmaputra, flowing with a steeper gradient through regions of high rainfall possesses a greater velocity, and consequently only larger materials are deposited. As a result, the soils of the Brahmaputra valley in Assam are largely sands and sandy loams. On the other hand the Surma river and its tributaries are very sluggish streams because they flow almost on a level plane. As a result finer materials are deposited along their banks This tends to make the soils of the Surma valley consist largely of heavier types of soil like silt and clay. The clayey or colloidal character of the soil in the Surma valley is further increased by the larger amount of rainfall which occurs in this region.

Closely related to the type of soil of the Indo-Gangetic alluvium are the **desert deposits** of the arid region lying between the Indus valley proper in the west and the Aravalli hills in Rajputana to the east and from the coast in Sind to Delhi, Lahore and the northwest area of the Punjab. The greater portion of this area consists of soils which were brought down from the Himalayas by rivers some of which

are now extinct, like the Saraswati which is believed by some geologists to be the river flowing in the bed now occupied by the Ghakar and an extension of it through Rajputana to the sea near the mouth of the Indus.

This section is now covered by wind-blown sand from the western coast, and consequently the whole region is sandy and unproductive, although there are certain patches marked by present towns where underground or canal water is available, thus enabling a certain amount of cultivation to be carried on. The soil in this area, however, improves gradually from the coastal regions towards Delhi. Most of this area is occupied by the so-called Thar or Great Indian Desert, which occupies an area of about 40,000 square miles. Shifting sand dunes is the outstanding characteristic of the soil of this entire region. This is also the soil characteristic with more or less variation, of the whole north and northwest Rajputana and parts of the southern Punjab, although certain parts have better soils than others. The sandy wastes shade off into loam soil in the direction of the Luni river flowing in the eastern part of the area to the Rann of Cutch. A greater part of this area, although lying in the track of the southwest monsoon winds from the Sind and Kathiawar coast, does not receive rain. A greater portion of the rain that falls in this area, especially in the southwestern portion of it, comes from cyclonic downpours from storms which have travelled westward from the head of the Bay. Some of the soils are impregnated with alkali salts which are believed to have been blown in from the coast of the Arabian Sea.

In Sind the outstanding soil type is plastic clay which is a deltaic alluvium that has been brought down and deposited by the Indus river. Where water is available this soil becomes very productive.

The only figures available giving the chemical composition of the soils of these regions, are for soils near the Indus river in the district of Dera Ghazi Khan. These figures indicate that these soils contain a sufficient amount of potash, a fairly high percentage of lime, a greater amount of phosphoric acid than is generally found in the soils of other parts of the Indo-Gangetic alluvium, but less nitrogen and are therefore greatly in need of this fertilizing constituent.

In addition to those areas mentioned above in which alluvial soils are found may also be mentioned the soils found in the **submontane**

regions at the base of the Himalaya mountains. These soils are also of alluvial origin. But they are usually gravelly and more sandy in texture than those found in the plains. They are therefore more porous and well drained, and are usually characterised by the presence of fairly large pebbles deposited by streams which came down from the Himalayas. They thus form a continuous belt along the Himalaya mountains. These soils are usually known as *bhabar* or "alluvial fan" deposits. Below this belt of soil and mostly confined to the United Provinces, Bihar and Bengal, there is a belt of low marshy land where the soil is of a heavy texture, and therefore poorly drained, which is known as *terai* or bog soil. The regions in which these soils occur usually possess a high rainfall and also a comparatively high humidity which favour these marshy conditions. The texture of the soil in this region usually ranges from clay loam to heavy clay. A great portion of these areas where the soil is not too swampy is covered with dense forests such as in the Pilibhit, Bahraich, and Gorakhpur districts of the United Provinces, and in north Bihar.

Another type of soil found alongside of the Indo-Gangetic alluvium is that known as loess or **wind-laid soil**. This is a type of soil found in the northern Punjab. In character it is similar to the loess soil found over a very large part of the valley of the Hwangho in China, in the central part of the United States and also in the valley of the Rhine in Germany and in northern France and Belgium. This is a fine silty soil and is usually of a yellowish colour.

THE BLACK COTTON SOIL.

The second important soil group of India is that known as the *regur* or "black cotton soil", which covers an area of about 200,000 square miles. It covers a large portion of the Bombay Deccan, the Malwa plateau, the greater portion of the Central Provinces, Berar, and parts of Hyderabad, Gujerat, Kathiawar. It is also found scattered in patches as far south as the Tinnevelly district of the Madras Presidency. Similarly such patches of this soil occur in Rajputana to the east of the Aravalli hills and northward as far as the States of Bundi and Tonk. In the east they are bounded by the Bundelkhand region. This soil is especially adapted to the growing of cotton, hence the name of black cotton soil given to it.

This soil varies greatly in colour, consistency and fertility, but possesses the constant character of being highly argillaceous (clayey) and somewhat calcareous. It has also a tendency to become very adhesive when wet, and to develop deep cracks when dry. Some of these cracks have been found to be four to eight inches or even more in width and may penetrate several yards into the soil. Considerable quantities of soil material fall into the cracks on account of the action of wind and water, which leads to the mixing and slow circulation of the soil by the swelling and contracting of the colloidal masses when wet and dry respectively. This process is mainly responsible for the characteristic of the soil of having no change in colour to the depth of six to ten feet. The high degree of fertility of the black cotton soil is well-known. Some of these soils are said to have been under cultivation with practically no manuring for a period of about 2000 years and are still fairly productive, although some especially those in the higher regions, are rather poor.

These soils contain a large quantity of calcium and magnesium carbonates, and are fairly rich in iron, lime and alumina. But their nitrogen content is very low, which makes it difficult to explain their fertility. The potash content is very variable, with a maximum of 1·14 per cent., but on the whole the average is fair. The soils are also lacking in phosphorus and organic matter.

As to the origin of the black cotton soils of India, it is generally believed that they are soils formed in place (*in situ*), that is residual soils, which have been formed by the weathering of the "trap" material, which consists largely of basaltic rocks brought up through the fissures by volcanic eruptions of a previous geological age. While on the whole this theory appears te be the most probable, it cannot be generally applied to such soils as are found in Gujerat and Kathiawar where these soils are probably of estuarine or marine origin or they might have been brought down by rivers flowing through the higher black soil areas. In some cases these soils might have been formed by lagoons or back waters near the sea, as Blanford has pointed out in connection with the formation of the black soil found in Trichinopoly and Pondicherry. In the latter place *regur* was noticed to be in process of formation in a nearly dry lagoon separated from the sea by a sand pit.

The black colour of these soils was formerly attributed to the presence of accumulated humus. But Annett assigns their black colour to the presence of titaniferous magnetite and of one to two per cent of humus. Leather on the other hand attributes the black colour to some mineral substance rather than to humus. Harrison and Ramaswami Sivan claim that the colour of the black soil is probably due to a colloidal hydrated double iron and aluminium silicate which possesses the properties of ordinary clay, as well as to the presence of some organic compound of iron and aluminium.

Black cotton soil is the predominating type in the Central Provinces. The whole province may be divided into four soil areas. The first is the Narbada valley and the open and level portions of the plateau of the Vindhya and the Satpura Ranges. The second is found as a shallow black soil in a thin sheet over the surface of the basaltic rock from which it has been derived. The area which comprises this type of soil includes Nimar, Wardha, West Nagpur and the regions south of Chhindwara. The third is mainly sandy, or gravelly soil with stoney uplands of the Vindhya and Satpura ranges and the hilly country to the south of these ranges. The fourth is a yellowish sandy soil derived from metamorphic or crystalline rock, and is found in the basins of the Wainganga and Mahanadi rivers including the south of Balaghat, Bhandara and Chanda and the three Chhattisgarh districts. Of these four areas, the first two contain different types of black cotton soil. The former, that is the soil found in the Narbada valley and in the level spaces of the Vindhya and Satpura plateau, is of considerable depth. It is believed to be alluvial (formed by the deposits of decayed vegetable matter through the agency of rivers and streams), or the result of the weathering of "trappean" or volcanic rocks, or of both agencies. The type of black soil found in Nimar, Wardha, West Nagpur and South Chhindwara is on the whole a residual type, that is one derived from the rock underneath it. The soils of the other two areas in the province are not black cotton soils and therefore form a class by themselves. They are generally poor soils but respond readily to the application of manure and water.

In Berar, the central valley possesses a better soil than any in the Central Provinces as it is a deep, rich, black and exceedingly fertile loam. This soil is usually of very great depth with a thick underlying

stratum of yellow clay and lime. In the vicinity of the hills, however, the soil is light and shallow and consists mostly of *murum* and is on the whole a poor soil.

In Hyderabad the soil area may be roughly divided into the western and eastern portions. In the former the soil is mostly black cotton soil, while in the eastern area the soil shades off into the red soils of Madras. However, patches of one may be found interspersed in the other.

In the Bombay Presidency the black cotton soil is confined mostly to the Deccan area. It covers the regions around Khandesh, Nasik, Ahmadnagar, Sholapur, Bijapur and Dharwar. Beyond Dharwar, to the south, lateritic soils are found which will be discussed later. In the Broach and Surat districts of Gujrat an alluvial type of black cotton soil predominates. In addition to the black cotton soil there are also sandy soils of alluvial origin which occur mostly in the Ahmedabad district, and these shade off into the rich loams of Kaira.

In Central India we find a greater variety of soils, although the black cotton soil predominates, especially in the Malwa plateau. To the north of the Malwa plateau in northern Gwalior the black cotton soil gradually shades into poor soils more or less reddish or at least lighter in colour than the typical black cotton soil. The soils in the Bundelkhand region are also poorer in texture than those of the Malwa plateau and are somewhat reddish in colour. In the Nimar area of Central India south of the Malwa plateau there is a preponderance of lighter soils compared to those of the Malwa plateau.

The northern limits of the black cotton soil are the States of Bundi and Tonk in Rajputana.

THE RED SOILS.

The red soils form another important group of soils in India These are commonly found in the Madras Presidency, Orissa, the Garo and Khasi Hills in Assam, Eastern Bundelkhand, in the United Provinces, and to some extent to the southeast of the Aravalli hills in Rajputana. They are derived from ancient crystalline and metamorphic rocks

which consist mostly of granites, gneisses and schists with subordinate rocks rich in ferro-magnesian minerals. They are believed to be of sedentary formation. In comparison with the black cotton soils, these are found to be poorer in lime, potash and ferric oxide and are also low in phosphorus content. However, they are very variable in character, and cannot therefore be easily classified either chemically or according to their physical characters. And although practically all of them possess the red tint, many of the so-called "red soils" of Madras have no red colour.

The term is used in a very vague sense, apparently to distinguish such soils as are not black. Consequently some alluvial soils are probably also included in this group. Some red soils however are laterites or lateritic soils and are of quite a different nature from the other red soils. The predominating form of red soil is a sandy clay, coloured red by iron peroxide.

In Madras these red soils cover the part of the Deccan plateau not occupied by black soils as above mentioned, and central and southern Madras as far south as Trichinopoly. The typical red soils predominate in the district of Chingleput, Salem, Trichinopoly, South Arcot and the upland soils of Vizagapatam and Ganjam. The black soils sometimes occur in patches throughout these areas.

THE LATERITES.

Laterites and lateritic soils compose the fourth type of soil which is characteristic of India and the tropical regions. Normally laterites are argillaceous material impregnated with iron peroxide, and are mottled with various tints of brown, red and yellow while a considerable proportion sometimes consists of white clay. They usually harden when exposed to air. Laterites occur in a large number of forms and contain a considerable quantity of hydrates of alumina. There has been a great deal of confusion as to the use of the term laterites, as there is a lack of agreement among soil scientists as to the nature of the rock from which it is derived and the character of the soil associated with this term. The term laterite should be used to denote a soil formed *in situ* by the leaching of the bases and much of the silica from the original rock, leaving a residue having certain amounts of

alumina uncombined with silica. Laterite soils are more often formed under conditions of high rainfall which helps to remove silica in solution through the process of leaching, leaving behind the hydroxides of alumina. Chemically it is very difficult to indicate the common characters of laterite soils. In general, the best classification of laterite soils is possibly one based on the examination of the complete soil profile and the determination of the amount of hydrated alumina in the soil.

These soils are found on the summits of plateau and hills of the Deccan, Central India, the Central Provinces, the Eastern Ghats, South Canara, in the Bombay Presidency, and Malabar and in certain parts of the hills of Assam.

Agriculturally these soils are found to be poor in plant nutrients. They are low in nitrogen content as well as lime, magnesia and potash Sometimes the amount of phosphoric acid and humus is high, the phosphorus present being probably in the form of iron phosphates.

While these soils are on the whole poor they may be improved by tillage and proper manuring.

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CHAPTER VII.

SOIL MANAGEMENT.

PART I. TILLAGE.

From the view-point of agriculture, soil is really a medium for crop production. Therefore consideration is given here mainly to such scientific principles as have some bearing on practical soil management. It is hoped that this will help the farmer and practical agriculturist to adopt better systems of soil management which will result in the economic production of crops, and also in passing on to the future generations a soil with a fair degree of fertility.

One of the most common and practical methods which the agriculturist adopts in his management of the soil is what is known as tillage. This operation influences not only the physical condition of the soil but also its chemical and biological condition. One of the practical agriculturists of the eighteenth century in England made the remark that "Tillage is manure". Although this statement may not be literally true, yet it is common knowledge that tillage improves soil. By tillage is meant the working of the soil by the use of certain implements. This term, therefore, includes such farm operations as ploughing, harrowing, grubbing or cultivating, planking, hoeing, ridging and furrowing.

Some of the main objects of tillage are the following:

(1) To loosen the soil for the deposition of seeds.

(2) The destruction of weeds.

(3) To cover up rubbish, manure and crop residues.

(4) The loosening of the soil to allow the maximum absorption of water.

(5) The exposure of the sub-surface soil to air and sunlight for the destruction of disease organisms.

(6) The destruction of insects by exposing eggs and larvæ to birds and climatic elements.

In short, tillage aids in the production of suitable physical, chemical and biological soil condition. Most farm operations are done with the object of producing the most desirable physical condition in the soil which is known as "good tilth". Such a condition is very essential for the proper germination of seed.

PLOUGHS.

Of the different forms of tillage, ploughing is perhaps the most universal and is one of the most indispensable operations on the farm Although the plough is probably the best granulating agent under favourable soil moisture conditions, it may become very harmful as it is also the best and most effective puddling agent when the soil is too wet. Consequently this implement should be used with considerable judgment especially in the case of clay soils. The correct stage at which the various types of soil should be ploughed is roughly determined by taking a mass of soil and pressing it in the hand. If the soil retains its form and does not show the presence of free water, the soil is fit for ploughing. Sandy soil, however, can be ploughed when the moisture content is high or low without any detrimental effect to the soil.

In general, ploughs are of two types, the *desi* and the mouldboard.

A *desi plough* consists of the following parts :—

1. A tongue of wood fitted with an iron point.
2. A handle for holding the plough.
3. A beam for attaching it to the bullocks.

The *desi* plough varies considerably as to its size and form in different parts of the country depending mainly on the size of the bullocks of the local breed, but also on the type of soil in the region. These ploughs have been evolved through generations of experience and they generally suit the height of the bullocks in the district. Any change or adjustment made in these ploughs is likely to make them unsuited for the bullocks of the locality. This may be due to the fact that the forces acting on the implement as summed in the resultant or line of draught do not pass through the centre of resistance of the implement, and therefore the plough does not ride steadily at a uniform

depth. If the angle is too great, the plough may proceed in a series of jumps, doing very poor work and making it harder for the bullocks to pull. The effect of a slightly incorrect adjustment in a plough of this type is not so apparent as it is in a plough drawn by a flexible draught rope or chain. In Bundelkhand the plough is very heavy weighing about 3½ maunds and stirs the soil to a depth of nine to twelve inches. On the other hand the *desi* plough in Bengal is very light and ploughs to a depth of about 2 to 3 inches only. Usually the local conditions determine the form and size of the plough. It is always advisable for a new comer to a locality to use the local plough or implements approximating its action on the soil until he has gained sufficient experience of local conditions. Later he may wish to make a change.

The chief characteristics of the *desi* plough are as follows: —

1. It possesses no mouldboard and consequently cannot invert the soil.
2. The furrows are v-shaped and therefore unploughed strips are left between furrows. The land has therefore to be ploughed in different directions in order to break up these unploughed strips.
3. It ploughs a smaller area in a day than that usually covered with a mouldboard plough.

Summer ploughing with mould board ploughs at the Allahabad Agricultural Institute

A mouldboard plough consists of the following parts :—

1. The body or frame to which other parts are attached.
2. The beam.
3. The mouldboard.
4. The share.
5. The handle.

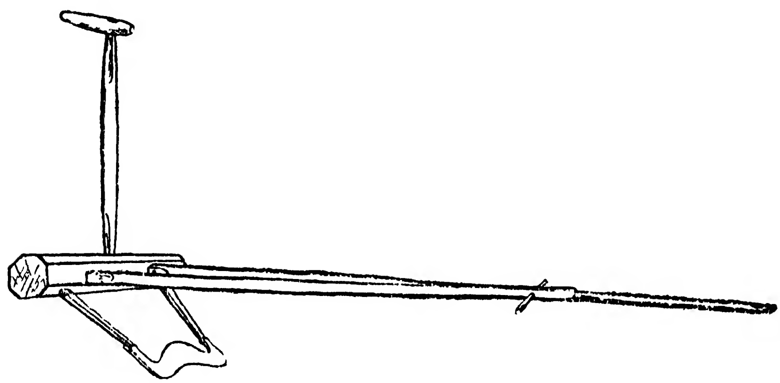
There are several types of mouldboard ploughs that are now being used in this country. The most common are the Meston and the Chattanooga ploughs. The Rajah plough at one time was more commonly used but at present it is being displaced by other types of ploughs, such as the Chattanooga in the Punjab. Mouldboard ploughs have a special characteristic of being able to invert the soil. They also plough deeper than a *desi* plough. This type of plough is particularly useful in the ploughing under of green manures, manures and crop residues. It is equally useful in weedy fields since it buries weeds and aids in keeping the land clear. Most of the mouldboard ploughs are heavier than the common *desi* plough which fact makes the former unpopular with the Indian farmer. The Meston plough is however not very much heavier than a *desi* plough and can easily be drawn by the average Indian bullocks. It can also be carried to the field like a *desi* plough. Some of the other disadvantages of the mouldboard ploughs are usually their higher cost and the difficulty of getting them repaired. The Meston plough, being light, is almost useless in heavy soils because it does not work well. For such soils a heavier type of plough, such as the "Rajah" is necessary, although it is more expensive. It has been claimed by some people that a further disadvantage of the mouldboard plough is that it tends to form a "hard pan" where used at a uniform depth from year to year. Of the different types of mouldboard ploughs, the Meston plough is probably the lightest and cheapest. Wooden parts for it can be easily made and fitted by a village carpenter.

As to the depth of ploughing, there exists considerable difference of opinion. Some believe that deep ploughing is beneficial in Indian soils, where as some others believe it to be detrimental as it brings to the surface the subsoil which is lower in fertility than the surface soil. However, recent experiments in this country tend to show that deep

ploughing in the Gangetic alluvium is beneficial to the crop. Experiences in the "black cotton soil" area, tend to show that increased depth and inversion show little advantage in crop yield, cost considerably more, and demand heavier and more costly ploughs which an average farmer cannot afford. However, for the more valuable crops, periodic soil inversion coupled with increased depth has usually given better results. But better yields and better returns on capital invested may be secured by substituting organic manures in place of the more expensive deep ploughing.

HARROWS AND CULTIVATORS.

Harrows, *bakhars* and cultivators (or grubbers) are also useful implements on the farm. These are of various types. The main



Bakhar.

object in the use of these implements is to pulverize the soil and comb out the weeds. They are also used to cover seeds that have been broadcast.

A harrow usually consists of a frame with teeth fixed to it with the object of stirring and breaking up the soil surface. The lighter ones tear through the soil, simply breaking up the lumps, while the heavier ones also do some dragging or levelling.

Some of the **harrows** used in this country are the following: (1). The spike-tooth or peg-tooth harrow, (2). The spring-tooth harrow, (3), The bar harrow, (4). The drag-harrow, (5). The chain harrow. Of

these, the spring-tooth or spring-tined harrow, as it is sometimes called, works a little differently from the others. In the spike-tooth harrows the teeth are rigidly fixed to the frame, whereas in the spring-tooth harrow the teeth are curved and possess a certain amount of springiness so that when a serious obstruction is encountered by one of the points, the tine will spring back and release itself from the obstruction. In this way the obstruction is prevented from throwing the entire implement off its level. There is also a certain amount of vibration of the spring-tine which is believed to increase its pulverizing action in the soil. However, the springiness often prevents this harrow from properly tearing up matted patches of *dub* or other grasses which produce sods. This type of harrow is most useful in lumpy clay soil or in stoney land. But a spike-tooth harrow may be conveniently used on light alluvial soils. These harrows can cover about 3 to 4 acres in a day with one pair of bullocks.

The bar harrow is a modification of the spike-tooth and is made locally by village carpenters. Hence it is cheaper than the two previously mentioned. It consists of a wooden frame with pointed iron pegs. A drag harrow is very much like the bar harrow except that it is heavier. The extra weight of a drag harrow causes it to drag, thereby enabling it to level and compact the soil in addition to breaking the lumps or clods.

The chain harrow is generally used for covering up the seeds after sowing.

A disc harrow is another type which is heavy and rather expensive and hence not commonly used in India. It sometime takes the place of a plough.

Cultivators (or grubbers) are extremely varied in design. They are used chiefly to perform functions intermediate between those of the plough and the harrow. They remove weeds by cutting and bringing up their underground parts to the surface and pulverize the soil. In general they stir the soil just as does a *desi* plough. The following types of cultivators are commonly used in India.

(1) The horse-hoe cultivator.

(2) The *bakhar* of Central India and Madras.

(3) The Planet Junior Cultivator, a type of wheel-hoe.

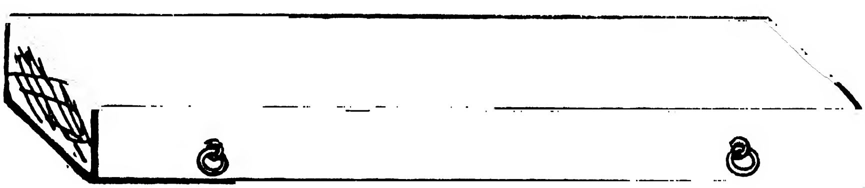
The horse-hoe cultivator is adapted for use between the rows of, a crop sown in lines, such as cotton, or it may be used on fallow land. Most horse-hoes can be changed to any width varying from eighteen to thirty-six inches. Such a cultivator can cover about three acres a day when used for cultivating an unplanted field. When used for inter-culture between rows it can also cover about three acres in a day. This cultivator can also be used for ridging, and when so used it can cover about two acres a day.

A *bakhar* is another type of cultivator commonly used in Central India. It consists of a blade usually about a foot long fixed to a body to which a beam is attached. It is used for interculture most of the crops in the region being usually sown in lines. This is an indigenous implement, and is cheap, light and inexpensive, and can be easily constructed and repaired by a village carpenter.

A wheel-hoe is a modification of the horse-hoe cultivator. It is light and is pushed by a man, instead of being pulled by bullocks. It possesses numerous attachable parts, and is therefore adapted to a large variety of uses on the farm, especially in vegetable gardening.

SOIL COMPACTING IMPLEMENTS.

Another group of implements known as plankers, packers, crushers and rollers are commonly used on the farms in India. Their action is to compact the soil, to break clods and to level the surface. The best known and the most widely used in India is the planker, or *patela*.



Beam.

In Western countries a planker consists of several planks put together, each plank usually about six feet by ten inches by two inches, and arranged so that they overlap each other. In India it either consists of one large plank or a heavy wooden beam hence the operation is

sometimes known as 'beaming' or 'planking'. The planker when dragged over the soil crushes the clods and grinds them together, thus reducing their size. The soil is thus levelled, smoothed and to some extent compacted, depending to a great extent on the weight of the planker. Planking helps to bring more moisture in contact with the seeds sown, and hence the operation is usually adopted in the preparation of a seed bed.

Rollers and crushers generally resemble the planker in their function. In Western countries these are usually made of iron, but in India the farmers usually make them out of wood, as the iron ones are too expensive. These are not commonly used in this country except in certain localities such as Karnal and Rohtak near Delhi.

Another important agricultural implement is the **drill**. This is one of the most valuable implements in modern agriculture. The indigenous method of sowing seed is usually to drop the seeds behind the *desi* plough by broadcasting. Drilling however, should be preferred to broadcasting for various reasons. Firstly, drilling aids in the proper distribution of seed Secondly, the seed is placed at an even depth in the soil, thus enabling all of the seed to be properly placed in the moist soil. Thirdly, germination is more uniform. Fourthly, the plants have equal opportunity of obtaining food, light and air. Fifthly, this facilitates hoeing and interculture. Sixthly, bullock power can be used for the interculture of most crops, thus reducing hand labour, and thereby reducing costs of production. This method of sowing is most desirable especially in dry-farming areas where there is a limited amount of moisture in the soil.

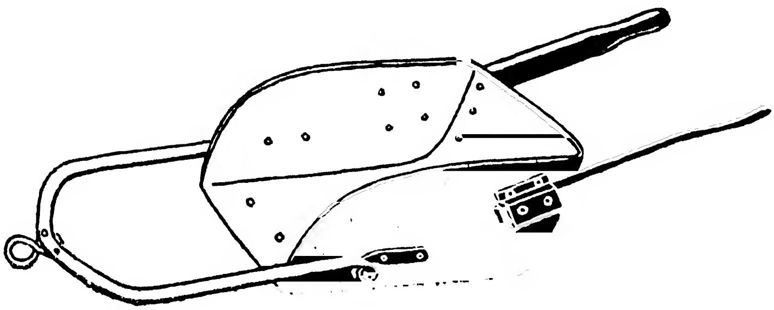
The method of sowing with a drill is not new to India. While the Indian farmer generally sows his seed through a tube attached to a *desi* plough and therefore is able to sow or drill only one row at a time, other types of drills have been developed which can sow or drill more than one row at a time. Even these have been used for centuries in some parts of India.

These drills usually consist of a body or frame to which a beam is fixed for attaching it to the bullocks, and a handle for holding. To the frame are attached furrow-openers, fixed at a definite distance from each other depending on the desired width between the rows, and to each of these openers seed tubes are attached. On the top of these

tubes a cup is securely tied through which the seeds are dropped into the furrows.

THE LEVELLER OR SCRAPER.

The leveller is still another implement commonly used on the farm. It is used for grading and levelling of uneven land, for the re-



Leveller.

moval of alkali incrustations from the surface of the soil, for "bunding" or throwing up embankments, and for the making of irrigation channels. Grading or levelling is a necessary operation for preventing soil erosion or excessive water run-off. The leveller is an especially useful implement in the levelling of land devoted to irrigation farming.

Land reclamation with scrapers at Allahabad Agricultural Institute

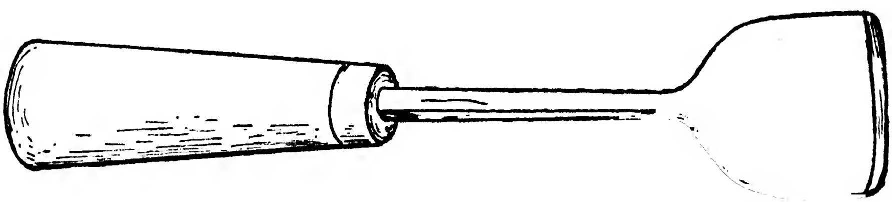
This implement consists of a metal scoop with a device for attaching bullocks and a pair of handles. The front edge of the lower portion of the scoop is kept sharp and is usually made of good iron. The implement is simple in construction. An ordinary American leveller holding about three cubic feet of earth, which can be drawn by a pair of bullocks is found to be most satisfactory.

HAND IMPLEMENTS USED IN TILLAGE.

Besides the larger implements mentioned above, the following are some of the common hand tools used for various types of farm operations:

(1) The *pharwa.*—This is a general purpose hand implement. It is used for hand digging, erection of small bunds, digging of trenches, irrigating, digging of certain root crops and for various other types of farm work.

(2) The *khurpi.*—This is probably the most widely used hand implement for weeding and mulching in India. There are various types and modifications in the various parts of the country. It consists of an iron blade and a wooden handle for holding.



Khurpi.

(3) A hand-hoe.—This is a western implement introduced into India, and its function is the same as that of the *khurpi*, namely weeding and mulching. But this can also be used for earthing and for irrigating. In this respect its function also resembles that of the *pharwa.*

(4) A hand ridger of *jandra.*—This is an implement commonly used for making small ridges as used in the production of irrigated wheat. It consists of a flat board usually about three to four feet long, about five inches wide, and one inch thick. At the centre of the

board a pole about five feet long is attached. Near the ends of the flat board two rings are attached for fastening a rope. This is operated by one man holding the pole slightly on one side of the place where the ridge is to be made and slightly pressing downwards, and another man holds the rope and pulls it towards himself. In this way a ridge is made.

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CHAPTER VIII

SOIL MANAGEMENT

PART II.—IRRIGATION AND DRAINAGE

In a country like India where long periods of drought occur, the continuous supply of water for the crops becomes a very important factor in economic crop production. For these periods of drought, irrigation, which may be defined as the artificial application of water to the soil for the purpose of growing crops, becomes very necessary, in places where the rainfall is deficient. The rainfall in India is also very unevenly distributed, most of it coming within a very short period followed by a period of drought. Again, while some regions in India receive too much rain, other regions, on the whole, do not get sufficient for normal crop production. For these latter regions, the application of water by irrigation becomes essential. Thus the areas including Sind, the North-West Frontier Province, the Punjab, the United Provinces, a large portion of Bihar, most of Madras, most of the Bombay Presidency, portions of the Central Provinces and the major portion of Rajputana are included in this region. Aside from this the Indian rainfall is liable to fail entirely at times or to be seriously deficient. Hence the method of storing water has been practised in India from very early times.

TANK IRRIGATION

The most primitive means of storing water in India for irrigation purposes is the tank. Tanks vary in size from works like Lakes Fife and Whitting in the Bombay Presidency or the Periyar Lake in Travancore, holding several billion cubic feet of water to small village tanks irrigating only a few acres. Another important group of such tanks are found in the Chingleput district which irrigate about 4000 acres and are said to be 1100 years old. The highest development of tank irrigation is in

Madras. The area irrigated from tanks in India is approximately 8,000,000 acres.

There are usually wo ttypes of tanks (1) the submerging tank, and (2) the irrigating tank. The first is used for storing water during the rains, and then emptied in the month of October to expose the tank bed in order to allow the preparation of the soil for sowing the *rabi* crop. But an irrigating tank is meant to hold as much water as possible, and the water is withdrawn from time to time for irrigating the adjacent fields.

A tank usually consists of (1) a bund for retaining the rain water, (2) an escape weir for the removal of surplus water in years of heavy rain, (3) a sluice to draw off the water in order to empty the tank and (4) one or more channels for distributing the water.

CANAL IRRIGATION

This system of irrigation has been known in India from very early times. The remnants of an ancient irrigating channel of the sub-montane districts of Northern India which have been covered by forest growths and the Grand Anicut or the Cauvery in Madras, indicate the early attempts at canal irrigation. In Sind and the Western Punjab the practice of withdrawing the flood waters of the River Indus for purposes of irrigation is very ancient. In the Rohilkhand region, some of the modern canal systems follow the older canals of early centuries. In more recent times Feroze Shah and Akbar constructed canals to take water to the Hissar district in the Punjab. In fact, the early British engineers directed their efforts towards the improvement of the existing indigenous works instead of the construction of new irrigation projects. Some of the recent works of the British Government have enormous capacities and serve very large areas. In 1878-79 the acreage under canal irrigation was estimated to be ten and a half million acres. But during the last fifty years the Government's new projects have increased this area to approximately-thirty one and a half million acres. This development of networks of canals and other irrigation structures has been very phenomenal; so that India can now boast of some of the most magnificent irrigation projects in the world.

The areas under canal irrigation according to provinces is given below:—

	Acres.
Punjab	11,343,000
Madras	7,489,000
Sind	4,728,000
United Provinces	3,786,000
Bihar and Orissa	869,000
North-West Frontier Province	399,000
Bombay Deccan	388,000
Central Provinces (excluding Berar)	352,000
Bengal	48,000
Rajputana	29,000
Baluchistan	21,000

Some of the most important irrigation systems in India are:

(1) The Lloyd Sukkur Barrage in Sind. This is the greatest work of its kind in the world. The area irrigated by this canal is approximately 2,70,000 acres.

(2) The Cauvery (Mattur) project in Madras. This scheme is designed to irrigate about 1,300,000 acres of rice fields situated 125 miles away from the dam, in the Cauvery delta.

And (3) The Sutlej valley canals in the Punjab. This project is designed to irrigate 5,108,000 acres or eight thousand square miles in the Punjab, Bhawalpur and Bikaner States.

WELL IRRIGATION

About 30 per cent. of the total irrigated area in India is supplied by wells. This water is more carefully used, as every drop of it has to be lifted, and is also used for high grade crops. It is, therefore, estimated that well-irrigated lands produce at least one-third more than the canal-irrigated lands. Wells in India are of various types. Some are very *kuccha* and are simply holes to the strata of soil where subsoil water exists, whereas some others are made of masonry and are more permanent In some places these wells are also quite deep, as, for example, those found in Bikaner State.

Wells which are sunk through pervious strata only to subsoil water are known as "shallow wells", while those that are sunk through

an impervious layer of soil usually clay, and tap subsoil water below the impervious strata are known as "deep wells". Besides these, there is another type known as artesian wells in which the water rises to the surface without being pumped. But the possibilities of artesian water supply in India are not fully understood and have been very imperfectly tested. But even if they are as good as some would believe them to be, there appears to be no utility in any great scheme of irrigation from them for agricultural purposes.

METHODS OF LIFTING WATER

There are various ways of lifting water in India. The most common water-lifts used are the following:—(1) the *mot* or *charsa*, (2) the Persian wheel, (3) the Baldeo *balti*, (4) the chain pump, (5) the swing-basket, (6) the Egyptian screw, and (7) pumps.

The Mot or Charsa.—This is the most common indigenous method of lifting water from deep wells. It consists of a large leather bag which holds from about 24 to 42 gallons of water, attached to a rope which usually passes over a pulley and is drawn by a pair of bullocks. The animals are made to walk down a slope (or inclined plane) when lifting the leather bag full of water. This bag is sometimes provided with a self-delivery tube which empties the bag when it reaches the top of the well. In certain regions the *mot* is not provided with a self-delivery tube and therefore requires an additional man for the purpose of emptying the bag. When the bag is not provided with a self-delivery tube the rope is released from the bullocks and the bag falls in the well by its own weight, while the bullocks turn around and walk back. In the meantime the bag is filled again with water, and the rope is again attached to the yoke of the bullocks. Sometimes two pairs of bullocks are used, and this requires an additional man to handle them. By this method more water is lifted within a certain period of time. But in the case of the *mot* with the self-delivery tube only one pair of bullocks is used, and the rope is not unhooked from the bullocks which are required to back up to the well. In this method of operating the *mot*, only one man and one pair is required, but the backing of the bullocks to the well considerably slows up the work. Sometimes more than one *mot* is

used in one well, but generally not more than two. By this method of lifting water using one *mot* from a well about 60 feet deep, about 60 tons or 1620 maunds of water can be safely raised in eight hours. This is equivalent to approximately a half acre-inch of irrigation water.

The Persian Wheel.—Lifting water from wells which are not too deep can be successfully carried out by means of a Persian wheel. This method of lifting water is common in the Punjab, parts of the United Provinces, Kathiawar, and parts of Rajputana. In its simplest form a Persian wheel consists of a wooden drum which turns on an axle and rotates a chain of buckets. In the old indigenous type the chain consists of a special type of small clay pots, tied together by means of ropes usually made of some kind of straw; but in the present-day improved types the drum and axle are made of iron as well as the chain, and the buckets are usually made of galvainzed iron. The old type is very heavy, whereas the improved type is much lighter. Recently Persian wheels have been made with the axle turning on ball bearings which makes this machine much easier to operate and more efficient. In places where the water is near the surface, larger buckets are used, but in wells where the water is deeper the size of the buckets is generally reduced, because the weight of the chain and the number of buckets increases with the increase in the depth of the well, and consequently less water is lifted.

This type of lifting water is not only confined to wells, but is also used sometimes for raising water from streams or tanks.

This water-lift is generally operated by bullocks or a camel and usually only one man is required to work it. In general a farmer leaves a boy to operate it while he attends to the irrigation water in the fields. The improved Persian wheel is becoming more and more popular because it is probably more efficient than the *mot*.

The Baldeo Balti.—This consists of two boat-shaped water-lifts which are tied with a rope or string which passes over three pulleys. They are arranged in such a way that when one of these boat-shaped lifts rises and discharges its water, the other one goes down and re-fills, the water entering the lift by means of a valve. This water-lift may be arranged in such a way that it may be operated with one or two bullocks.

The Chain Pump.—In construction this is similar to the Persian wheel. A pulley is fixed to a shaft which is turned either by a handle when human labour is used or by a gear when bullocks are employed. An endless chain passes over the pulley and is fixed in an iron pipe usually about four inches in diameter and which extends from the top of the well to a bell-mouthed end fixed about two feet below the surface of the water in the well. This pipe, for depths of more than 10 feet should be fixed on a beam built into the masonry of the well. The chain is fitted with circular discs which have about the same diameter as the tube and therefore fit the tube. These discs are arranged about one foot apart on the chain. The chain ascends inside the pipe, bringing the water with it and discharging it into the channel at the top. The discs are sometimes fitted with leather washers which help to reduce the leakage of water back into the well. However, these washers have to be repaired or renewed from time to time. This pump works well to a depth of about 20 feet, but it is doubtful whether it will work efficiently for lifting water from wells more than 20 feet in depth, on account of leakage of water from the discs. The capacity of the chain pump depends upon the depth of the well and the size of the pipe.

The size of the pipe usually varies with the depth of the well; that is, the deeper the well the less is the diameter of the pipe.

The following are the approximate capacities of the Chain Pump at different depths and varying diameters of the pipe:—

Depth of well in feet.	Diameter of pipe in inches.	Approximate quantity of water in gallons per hour.
10	5	6000
20	4	2500

The Swing Basket.—This usually consists of a metal *tagari* (basket), to which ropes are fastened on opposite sides. It is operated by two men who swing the basket by swinging the ropes. Each swing catches some water and lifts it to an upper channel usually one to three feet higher. This is most commonly used for lifting water from ponds or *jhils* to a channel on a higher level. The quantity raised depends largely upon the ability and strength of the men operating it.

The Egyptian Screw.—This consists of a wooden cylinder about 16 inches in diameter and four to five feet long containing a screw made of a series of planks. The cylinder is fastened to a support in the water and at the delivery trough. It is usually fixed in an inclined position at an angle of about 35 to 45 degrees. The cylinder is operated by turning it, thus causing the water to rise up through the screw into the delivery trough. This water-lift is commonly used for shallow depths varying from two to three feet. Its use is for similar conditions to those for the swing basket, that is, for lifting water from ponds or *jhils*.

Pumps:—Pumping from wells using mechanical power, either oil or steam-engines, is now becoming more and more common in this country. Power pumps may be used economically where considerable water is required, say, at least 10,000 gallons per hour. Most wells will not stand the withdrawal of such large quantities of water, as blowing or the sanding or silting up of the well, may take place. In order to avoid this, a special type of well known as the tube-well is generally employed. For the proper installation of a tube-well, it is essential that the proper strata of water be tapped or found. The installation of a tube-well is usually expensive and requires technical knowledge.

There are various types of pumping plants which are successfully used in this country for lifting water from tube-wells. Local conditions and requirements must determine the type and motive power best suited for individual cases.

SEWAGE IRRIGATION

A more recent development in the field of irrigation in this country is sewage irrigation. In large cities sewage disposal is a pressing problem. But this sewage water, when conducted to cultivated fields, has been found to be valuable in crop production. Hence, there are two main objects sought in the use of sewage in irrigation. The first and foremost is to oxidise and render harmless the bacterial organisms which it contains. The second object is to utilise the water together with the organic matter and fertilizing materials which it contains, in the production of crops. Sewage is mainly organic matter in the form

of human excreta, and water. However, the character of its contents varies with the miscellaneous refuse which it sometimes contains, such as rags, papers, vegetable trimmings, and the like. The organic matter consists chiefly of proteins in various stages of decomposition, urea, carbohydrates, fats, and oils.

Conditions in most parts of India are very favourable for sewage irrigation. In the first place, in most parts of India there is a continuous dry period, during which time of the year water containing these important manurial ingredients is of the greatest value in crop production. Secondly, loams and sandy loams, the types of soils which predominate in most parts of India, are well suited for this type of irrigation, because there is less danger of water-logging, even in humid climates. From the agricultural view point, sewage may be applied to any type of soil as long as it is not used continuously or in too large quantities. Sandy soils usually need artificial fertilization and are also usually deficient in water, and therefore are best suited to this type of irrigation. The agricultural value of sewage when properly applied to the soil has been sufficiently demonstrated, under varying conditions of soil and climate, and there is little doubt that it is desirable to use sewage for irrigation.

METHODS OF IRRIGATION

There are several methods of irrigation. But these different methods may be grouped under two main heads: (1) Surface, and (2) Sub-surface irrigation. In the sub-surface irrigation, the water is applied from below the surface of the soil and is thus subjected to less direct evaporation. Nevertheless, this method is not commonly used in this country and therefore it will not be further dealt with. Surface irrigation is the method generally employed in irrigated countries. There are several kinds of surface irrigation, the most common being the flooding and furrow methods.

The oldest and most common method of irrigating is to flood the surface of the land with water. This is known as wild or *open* flooding. Sometimes the areas to be flooded are ridged, that is a ridge is built on each side of a strip to be irrigated, the ridges serving as borders. This method is known as the *border* method of irrigation. The field

is divided into compartments or long strips and the water is applied to one compartment at a time. This is probably the most common method of irrigation in India. When the compartments or *kiaris* are made very small, the method is sometimes known as the *check* or compartment method.

Sometimes a series of furrows are made close together throughout the field and water is allowed to run in these for some time. This method is commonly known as the *furrow* method of irrigation. The type of soil, the slope of the land and the crop usually determine the length of the furrow and the distance between furrows.

Although the border method is most commonly used in India, the furrow method possesses several advantages which may be enumerated as follows: (1) The furrow method allows the farmer to control the quantity of water applied to his fields. (2) It enables the farmer to cover a larger area with a given amount of water. (3) It prevents washing of light soils. (4) It reduces evaporation. (5) It tends to prevent over-irrigation. (6) In regions where there is a possibility for the land to become saline, it tends to delay the rise of alkali. (7) It reduces baking of the surface soil. But this method has one great disadvantage which may outweigh all the advantages, especially in canal-irrigated lands; and that is that large volumes of water cannot be used in the small furrows. Further, it is difficult to add the same quantity of water to each furrow, and more difficult to give the same amount to the lower portion of the furrow as to the upper. It is also difficult to avoid run-off at the lower end.

THE WATER REQUIREMENTS OF CROPS

The application of the correct amount of water to the crop can be practised only when the farmer understands the quantity of water which is necessary to mature the crop. In canal-irrigated areas, where water is plentiful, it is generally not efficiently used, and as a rule, greater quantities of water are used than are necessary. As the result of this there has been in some areas a rise in the water-table, followed generally by alkali deposition or the formation of water-logged soils.

As regards the amount of water required by a crop, it is to be expected that a large plant or crop will require more water than a small

one of the same kind. Hence it becomes necessary to adopt a method of expressing the quantities which may be applied in all cases. One common method of expressing this quantity is the use of the "transpirtion ratio," which is the amount of water in pounds, transpired in order to produce a pound of dry matter. This ratio varies with different crop plants, soils and climatic factors. Thus, if the transpiration ratio of wheat is assumed to be 500, this would mean that for every maund of dry matter produced, that is grain and straw combined, it would require 500 maunds of water. Again, assuming that the amount of grain produced per acre is 15 maunds and that the yield of straw is 45 maunds; then the total dry matter produced is 60 maunds per acre. Therefore the amount of transpiration water necessary to produce this crop would be 500×60 or 30,000 maunds, or 2,460,000lbs. of water. Now since an acre of water 1 inch deep weighs approximately 227,000lbs. the amount of transpiration water necessary is equal to 2,460,000 = 11·3 inches. If it is assumed that 50 per cent. of the water applied to the soil is lost by evaporation, then the amount of irrigation water required to produce the above crop of wheat is 22·6 acre—inches. It should be noted that rainfall has not been accounted for in the above calculation. The following table gives the figures of the transpiration ratio of the different crops as worked out by J. W. Leather at Pusa. The figures taken are from the pot culture experiments only; no attempt is being made to summarise the results of the field experiments :—

TABLE XIX.

Showing the transpiration ratio of crops.

Crop	Transpiration Ratio
Wheat	450—650
Linseed	600—1000
Mustard	400—550
Peas	600—800
Barley	450—650
Oats	400—500

DRAINAGE

Drainage, which may be defined as the removal of surplus water from the soil whether by natural or artificial means is as important as irrigation. Drainage is especially important in those regions like the Punjab where extensive systems of canal irrigation are being developed. However, in the greater portion of India, land drainage is necessary, especially during the monsoon season. The following kinds of land more especially require drainage: (1) heavy clay soils from which rain water cannot drain easily, (2) low-lying flat areas, especially those more or less surrounded by hills, (3) lands with little slope and with an impervious sub-soil, (4) delta lands at the mouths of rivers, which generally require drainage in order to make them suitable for agricultural purposes, and (5) swamps, marshes, and *jhils*, such as those found in the *terai* regions at the foot of the Himalayas, especially in the United Provinces and in Bihar.

The following are some of the effects of drainage on the soil:—

(1) By removing the excess moisture which is in the form of gravitational water occupying the pore space in the soil, air containing oxygen is brought into those pores, which helps crop growth.

(2) Drainage improves the structure of a water-logged soil.

(3) Where the water-table is too close to the surface soil, drainage is very essential, as the water-table is lowered by this process which thus encourages root development.

(4) Drainage in regions where there is a possibility of the rise of "alkali" becomes very important as it helps in the permanent removal of certain salts which are dissolved in the excess water.

(5) Drained land can also absorb more rain water than undrained land, hence the process of drainage helps to prevent soil erosion.

It should also be remembered that drainage does not remove the available water from the plants. It does remove, however, the water that is in most cases detrimental to the proper development of most plants.

There are different types of drainage that can be used. The method depends on a number of factors, such as the topography of the land, the nature of the soil, the natural facilities for outlet, the area to be drained and the cost of labour and material. However, two types of drainage are generally used: (1) open channel and (2) closed drains.

Open Channels are the most common in India, because they involve less capital. They work satisfactorily where there is a large volume of water to be removed But the main objections to open channels are that they are difficult to keep free from weeds, they limit certain farm operations, and they occupy valuable land which might have been used for the growing of crops.

Open channels are usually V-shaped in cross section, but the slope of the ditch depends upon the type of soil being steeper in clay soil and less steep in loose sandy soils These channels should also be kept as straight as possible as erosion generally occurs wherever there is a bend in the channel. In the construction of an open channel care should also be taken to place the soil several feet away from the edge of the channel lest this be washed back into the ditch when heavy rain occurs.

Under-drains are covered drains running underground and allowing the water drained from the soil to flow away. In the construction of under-drains many methods and materials have been used. Among these, stones, brush, rubbish and tiles have been commonly used. The tiles are probably the most common. But these are rather expensive, which is probably responsible for their limited use in this country. In regions where stones are plentiful these may be used satisfactorily in the construction of the under-drains In regions where timber or brush is abundant, these may be placed in a trench and covered with soil. The water will usually flow through the porous space around the brush or timbers. After these are decayed, spaces are left which allow the passage of water for some years before they are filled up. Of these different types of under-drains the tile drainage, although expensive, is the most permanent and satisfactory. In connection with the laying of tile drains, one point should be noted. That is that the tiles are loosely laid so that their ends do not fit tightly to one another, but a small

space is left at the joints to allow the drainage water from the soil to enter the tile drain. Another important consideration in the laying of tile drains is to give sufficient slope to the drain, so that the water will flow off as fast as it reaches this drain.

The depth and distance between drains are matters of importance and usually depend upon a number of factors, the most important of which are: (1) the slope of the land and (2) the character of the soil. In general, the steeper the slope, the greater is the distance between drains. In fine-textured soils the distance between drains should be less than in the more open and light-textured soils. The depth of drains in sandy soils should also be greater than in clay soils. In general the depth in clay soils should be about 2 feet while in sandy soils it may be about 4 feet deep. In clay soils the drains may be placed at a distance of about 60 to 80 feet apart, whereas in sandy soils the distance may be made 150 to 200 feet.

SOIL EROSION

The prevention of soil erosion is now being recognized as one of the most important problems in agriculture. The losses in plant food nutrients caused by soil erosion in a country like India, where the entire cultivated area is subject to the monsoon rains, is tremendous. The losses in plant nutrients due to erosion have been estimated to be several times greater than the removal of plant food from the soil by the crops This impoverishment of the soil is largely due to the uneven distribution of the rainfall. Large amounts of nutrients are carried away in the run-off water to the low-lying lands or ultimately find their way to the rivers and then into the sea. Other factors which influence erosion are (1) the slope of the land, (2) the nature of the soil, and 3) the amount of vegetation on the surface of the soil A heavy downpour during the monsoon causes the water to run off the surface of the soil and collect into a stream which removes more earth as it goes along. When this goes on unchecked a small gully or *nallah* is formed The gullies usually increase in depth and width year by year forming small ravines, thus making the land, in a course of a few years, unfit for cultivation. Thus two types of erosion are generally recognized: (1) *sheet erosion*, or that taking place evenly over the surface of the soil, usually over a

large area and (2) *gully erosion*, or that which produces gullies or *nallahs*, and is thus more or less localised but slowly results in deep ravines. Such conditions are found in many parts of India, especially in that tract of the country south of the Jumna in Bundelkhand and in the Etawah district in the United Provinces, in parts of the Bombay Presidency, in Central India, and in certain hilly areas in the Punjab.

Sheet erosion may usually be prevented by a ground cover, such as grass of some kind, a cover crop, *bunding*, the spread of artificial mulches like litter or some organic refuse, and sometimes deep ploughing. This last method helps the absorption of rain water by the soil but at the same time ploughing makes the soil loose and under certain circumstances, it may be washed away more readily, of the different types of grasses used in this country as a ground cover, *dub* or *hariali* grass (*Cynodon dactylon*) has been found to be very effective in binding soil particles. In cultivated lands sometimes a leguminous cover crop, such as cowpeas and sunnhemp may also be used. Where *bunding* is resorted to, clumps of grass, such as those of *sarpat* (*Saccharum arundinaceum*) are sometimes grown on the bunds in order to bind the soil and thus minimise washing. *Bunding* refers to the construction of small *bunds* or embankments around fields to hold the rain water and thus prevent run off and ultimately erosion. This is widely used by farmers in India as it helps also to conserve rain water in the soil by maximum absorption, and thus raises the water-table in the soil and increases the available ground water in the wells.

If the land is not level, erosion may be reduced by having the slopes graded into horizontal terraces, which will vary in size according to the steepness of the slope. The terraces thus made usually resemble a series of steps along the slope. This system is especially useful for paddy cultivation where the country is hilly, but has a plentiful supply of water for irrigation purposes. Such terraces are also constructed for fruit and vegetable gardens and other crops on steep hillsides. In the construction of these terraces a low ridge is usually made on the front side of the terrace in order to prevent the washing off of the soil. Around its entire border a narrow drain or furrow with the proper slope should be arranged to collect surface water and direct it into drainage channels.

Gully erosion is an advanced stage of sheet erosion, and will not be serious if sheet erosion is prevented. The methods of controlling gully erosion depend very largely on the vólume of water that runs in the gullies. Where gully erosion has just started to damage the fields, a farmer can prevent further erosion and also can fill up the depressions by such methods as *bunding* or field embanking. A small earthen *bund* from 2 to 6 feet high is thrown up along the side of the field which is crossed by the gully. In this way one or two feet of water can be held until after the end of the rains. Or sometimes the farmer can stake stems of plants like *arhar* or *tur* and cotton at intervals of a few feet along the gully. These stakes are then made to support some straw or brush, which helps to slow down the flow of the water in the gully and in course of time fill it up with soil. In some cases old gunny bags may be partially filled with sod and these placed across the drain which may form into a gully. The bags are usually only about one-half filled with sod and placed in such a way that they lie flat on the ground across the small washes at the upper ends of gullies.

Where the gullies are larger, dams may usually be constructed across them. These dams are of various kinds depending usually on the amount of water to be taken care of. Among these the woven wire and the concrete or *pucca* brick dams are most commonly used. A woven wire dam consists of a row of strong iron or wooden posts set firmly in the ground across the gully generally placed about four feet apart. The posts should be set about 4 feet deep in the soil. The woven wire is then stretched across, touching the ground at all places and firmly secured to the posts. Brush and rubbish are then placed on the upper side of the wire in order to fill the meshes and thus catch the soil.

A concrete dam is more elaborate but also more permanent. It is usually constructed where a large area of eroded land is to be reclaimed. The foundation of the dam should be set in fairly deep, in order to prevent seepage along the bottom and sides of the dam. This precaution is all the more important if the dam is high and is meant to take care of a large volume of water. In a concrete dam a provision for an outlet is very necessary in order to prevent undermining.

A *kuchcha* dam may be made to serve the same purpose, but in this case, a spillway is more essential and adequate precautions must be taken to avoid erosion of any portion of the earthen dam.

Where rocks and stones are plentiful, gully erosion may be further prevented by filling in the gully at intervals with rocks. In this case also precaution is to be taken to prevent erosion around the rock or stone pile in the gully.

WATER-LOGGED SOIL

Water-logging is a phenomenon commonly found in different parts of India, especially in Bihar, the United Provinces and the deltas of rivers. This is due to improper draining of water from the soil. The phenomenon depends on several factors. Some soils are water-logged because the water-table is too close to the surface. When such is the case, the lowering of the water-table by proper drainage is very necessary. Certain soils are more subject to water-logging than others. Usually light sandy soils are free from water-logging, especially if the water-table is low, as these soils drain more easily than the impervious clay soils. However, some soils are subject to water-logging due to the presence of such deflocculating substances as sodium carbonate, which also results in the appearance of what is known as the "black alkali". This substance breaks up the soil structure, making it more compact and thus more or less impervious to the percolation of water. During the last few years there has thus been an increase of water-logged soils in canal-irrigated areas where the seepage water has raised the water-table and has thus increased the evaporation of sub-soil water, producing alkali incrustations on the surface. It is therefore of extreme importance to see that wherever irrigation systems are installed the water-table does not rise near to the surface as this may increase the acreage of barren lands in the area. Irrigation and drainage should therefore go hand in hand in any scheme of soil improvement.

The evils caused by water-logging are mainly due to the exclusion of oxygen which is necessary for chemical changes as well as bacterial development in the soil, and to the breaking down of the soil structure. Plants growing in water-logged soils usually show a diseased appearance and a yellowing of the leaves. This results in the stunted growth of a crop.

AIKALI SOILS.

The term "alkali soils" as commonly used has quite a loose or wide application. Alkali soils are so called when they contain a greater or less amount of water soluble mineral salts which exert an injurious influence on vegetation. The distinctive characteristics of these soils is the presence of an actual excess of sodium or potassium salts. The most commonly occurring groups are the "white" alkali which is saline in character and the alkaline "black" alkali. In white alkali the salts frequently present are the chlorides and sulphates of sodium and potassium and also sometimes the nitrates and carbonates of these metals, as well as the sulphates and chlorides of magnesium and calcium. The black alkali contains sodium carbonate usually in addition to the others. Some of the organic matter contained in the soil is dissolved by this compound imparting a dark colour to the soil. Where these salts are present in considerable quantities, they appear on the surface in the form of snow-white or brownish-black incrustations, known as *reh* or *kallar*. These salts originate usually from the underground water where the water-table is relatively near the surface. The salts have in some cases been present in the parent soil material or they may represent the remains of former salt lakes or inland seas. In some cases salinization has taken place by a rise in the salt bearing ground water, due directly to canal irrigation. The alkali soils of the Punjab and some parts of the United Provinces and Sind have been attributed to this rise of the water-table. Prior to 1884, alkali was unknown in the Nira Valley in the Bombay Presidency. In that year the Nira Valley irrigation canal was opened and since then the area of alkali is steadily increasing so that it now covers thousands of acres.

Alkali soils are generally associated with arid conditions where the annual rainfall is not sufficient to leach the salts out of the surface soil, and also where the hot rays of the sun cause the underground water to rise to the surface soil, and on evaporation, leave the dissolved salt as an efflorescence on the surface. In consequence, most of the alkali lands in India are found in the United Provinces, the Punjab, Sind, the North-West Frontier Province, and in the Nira valley and Kaira in the Bombay Presidency.

The different methods of reclaiming alkali lands may be grouped as follows:

1. Chemical methods.
2. Mechanical methods.
   (a) Flushing.
   (b) Leaching.
   (c) Scraping.
   (d) Trenching, and
   (e) Drainage.
3. The use of alkali resistant plants.

Amongst the *chemical methods* usually adopted, the most common is the application of a calcium compound usually calcium suplhate, by which the sodium in the alkali is replaced by calcium. Sometimes calcium carbonate is applied, and this, in the presence of farmyard manure, evolves carbon dioxide, forming the soluble bicarbonate from which the calcium can easily exchange with the sodium, resulting in the washing out of the exchanged sodium. However, chemical methods of reclamation are rather expensive. It is estimated that it will cost approximately Rs. 700 to Rs. 800 per acre for reclaiming lands affected with sodium corbonate, by the application of gypsum or calcium sulphate. These figures are given for lands heavily charged with alkali salts.

Flushing by flooding with water is another method which has sometimes been used. In this method the salt is removed by water running on the surface of the soil. This method can only be recommended if water is plentiful and cheap.

The Daulatpur reclamation scheme in Sind as well as the work done in Egypt for improving alkali lands shows that water may be used to leach out or wash down the soluble salts from the soil, thus rendering it fit for cultivation. The practical goal is reached when the salt content has been reduced to an amount which is harmless for crop production. This method also requires a good deal of water which must be cheap in order to make it practicable. In cases where the land is affected with black alkali, this method is very slow as the water percolates very slowly through the soil since this alkali deflocculates the soil, and renders it more or less impervious to water. The

water, therefore, must be allowed to stand for some length of time before any considerable amount of this substance can be leached out.

Sometimes the removal of alkali incrustations on the surface of the soil is done by *scraping* two to four inches of the surface soil. But this method is very inefficient, as the surface soil is usually also heavily charged with alkali salts. Hence removing the surface incrustations by scraping is practically useless, in that it does not remove the salt in the lower soil horizons.

Trenching consists in digging a ditch, placing all of its soil on one side, and digging another trench alongside the first one, placing the soil in the first trench so that the surface soil is placed at the bottom and the sub-soil is brought to the surface. Thus the alkali-bearing soil is buried at the bottom of the trench. This method requires considerable labour and is expensive. Further, the buried alkali soil at the bottom of the trenches usually moves upward again by capillarity in the course of a few years.

Drainage is usually used in connection with either flooding or leaching. But drainage itself is a method generally used to prevent the further rise of alkali, as in this way the permanent removal of the dissolved salts is secured through drains put in the soil.

Some people have advocated the removal of alkali by growing certain *alkali-tolerant plants*. It must be remembered, however, that plants cannot remove any large quantities of such salts. It is, therefore, almost always impracticable to remove alkali by cropping alone. However certain plants may render the soil better suited for cropping. Some of these resistant plants are *babul (Acacia arabica)*, wild indigo, beets, rice, *patsun* (Hibiscus cannabinus) and lucerne.

ACID SOILS

Unlike the alkali soils, there are some soils which are sour or acid. These soils are also unsuitable for the growth of most agricultural crops. Two main causes have been advanced for the development of acid in soils: firstly, the existence of free acids and, secondly, a deficiency of basic substances in the soil. These acid soils occur more commonly in humid regions, or in regions of high rainfall, although they are some-

times found in arid regions where swampy conditions exist. The development of acid conditions is generally attributed to the washing out of calcium or other basic substances by drainage or percolation. This acid condition may also be produced by the removal of basic substances by plants. The formation of salts of the bases with the soil organic matter may also produce acid soils. Sometimes these conditions may also be caused by the application of an excess of an acid fertiliser.

Acid soils have been found to be very injurious to such crops as lucerne, spinach, *jowar*, cauliflower, cabbage, carrots, lettuce, onions, muskmelons and beets. The following are also moderately sensitive to acid soils : wheat, barley, maize, cowpeas, cucumbers, brinjal, oats, pumpkins, radishes, soybeans, strawberries, watermelons, beans, tomatoes and turnips. Potatoes, rice, sweet potatoes and castor beans are considered to be adapted to acid soils.

This acidity in soils is generally determined by finding out chemically what is known as the pH value of the soil. A soil having a pH value of 7·0 is considered to be neutral. But if the value is below this, the soil is considered to be acid. In general, a soil with a pH value varying from 5·5 to 7·0 is considered to be medium or slightly acid, whereas a soil with a pH value varying from 5·0 to 5·5 is considered to be strongly acid. If the pH value is less than 5·0, the acidity is said to be very strong.

This acid condition in soils may usually be detected by the use of a blue litmus paper. This method consists of placing a blue litmus paper in contact with the moist soil to be tested. If the paper turns red, the acid condition is indicated. The deepness of the red colour usually indicates the degree of acidity in the soil.

In most cases this acid condition of the soil is corrected by the application of lime or basic fertilisers. But where swampy conditions produce this acid condition, the acidity may be reduced by proper drainage. The addition of lime to this drained soil, in most cases, will improve its crop-producing power.

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CHAPTER IX

MANURES AND FERTILIZERS.

Manures and fertilizers are substances applied to the soil in order to increase the amount of crop produced. The term "manures" as used at present is applied to organic manures and more especially to animal manures, whereas the term fertilizer is usually applied to chemical or commercial fertilizing materials. When green crops are ploughed under with the object of increasing the organic material in the soil such practices are referred to as green manuring, and the materials are known as "green manures", or "green plant-manures." Some writers sometimes make the distinction between substances which supply nutrients to the crop and those which improve the soil in some other way. The former are called fertilizers while the latter substances are known as "soil amendments." Thus sodium nitrate is regarded as a fertilizer, whereas lime is known as a "soil amendment". Such a fine distinction is not possible because these two substances serve both purposes; that is they supply nutrients as well as influence the condition of the soil. This is more true of animal manures which not only supply food materials for plants, but also materially improve the physical condition of the soil.

The soil is the store-house of the food materials which are being continually removed by crop plants, some of these do not naturally become available as rapidly as they are removed. It is therefore obvious that this continual removal of nutrients will ultimately impoverish the soil unless something is done to replenish the supply. The application of manures and fertilizers is the practical way of keeping up the fertility of the soil.

Materials which are commonly used as manures and fertilizers may be grouped as follows :

1. *Animal manures*:—These include the solid and liquid portions of animal excreta.
2. *Green manures*:—These include any crop grown and ploughed under for the purpose of increasing the organic matter in the soil.

3. *Chemical fertilizers* :—These include mostly the inorganic materials applied to the soil largely for increasing the supply of soil nutrients, especially nitrogen, phosphorus and potash.

4. *Special manures* :—These consist of materials which do not fall into the first three groups.

Animal manures :—On the farm where animals are kept—and they should be kept on every farm—their manure is a very important by-product. This material, if properly stored and applied to the soil, is one of the ways of returning a portion of the nutrients removed from the soil by crops. The proper storing and handling of manure on the farm is very important. One should also know the probable composition of different kinds of animal manures which are commonly produced on the farm. A proper knowledge of the importance of these manures would tend to discourage the wasteful practice of burning cattle dung. Of the animal manures, the cow and buffalo manures are by far the most common in India. However, small quantities of sheep and goat manures, as well as poultry manure, are available in some localities. The composition and value of the animal manure will usually vary with the kind of animal; the age, condition and individuality of the animal; the food of the animal; and the handling and storing of the manure before it is applied to the soil.

In general, poultry manure is the richest in the amount of fertilizing materials, as it contains per unit weight almost twice the amount of ammonia found in cow manure, almost three times the amount of phosphoric acid, and it also contains a little more potash than is commonly found in the cattle manure. Sheep or goat manure is also chemically better than cow manure. But this deficiency in fertilizing elements in cow manure is more than made up by the quantity of manures produced per animal. In addition to this, the large number of cows and buffaloes makes the cattle manure the most common and important of the animal manures in India. On account of the small quantities available, the other animal manures such as poultry, sheep and goat, and horse, are relatively unimportant in this country.

The composition of animal manure is affected by the age, condition, and individuality of the animal within the class. Usually a young, growing animal will retain a large amount of the fertilizing elements,

and consequently the manure produced will be poorer than from a fattened animal which will return most of the nutrient elements in the manure produced.

The character of the food given to the animal also affects the quality of manure produced. In general the richer the food, the richer will be the manure produced, since the animal usually retains only its bodily requirement and the remainder is returned in the manure.

Cow or buffalo manure is made up of two parts, the solid and the liquid. These are produced in the ratio of three to one. But the chemical composition as well as the physical properties of these components varies considerably. Hence their relative proportions will greatly affect the agricultural value of the manure. As the urine contains about 3 times the amount of ammonia per unit weight contained in solid or dung; the fertilizing elements in the whole manure are derived in approximately equal quantities from the liquid and the solid portions of the manure. Hence if the liquid portion is lost or not conserved, approximately half of the fertilizing constituents are lost and therefore wasted.

Usually conditions under which manure is stored in India are so unfavourable for the proper conservation of the fertilizing constituents that more than half of the agricultural value of the manure is lost or wasted. This is a tremendous and unnecessary loss to the country which can be prevented if the farmer is acquainted with the proper storing of manure.

The best method of storing manure has as yet not been worked out in this country. Even under the best conditions of storage so far known, about fifteen per cent of the manurial constituents are usually lost or wasted. However, probably one of the most efficient methods of conserving these fertilizing elements is the use of litter as an absorbent of the liquid portion of the manure. Some of the materials which may be used as absorbents of the liquid manure by spreading them in the animal shed for bedding are wheat, barley or rice straw, dry grass, dead leaves, unused fodder, and even substances like sand or saw dust where easily available. The litter is removed daily with the dung and properly stored in a pile or pit.

If a pile is made, it should be located on high land where there is good drainage, and the spot under the pile should be made slightly

hollow so that the liquid portion does not run off during heavy rains. The pile should preferably be protected from the sun and rain by some sort of cover or by a tree. The sides of the pile should be vertical or more or less steep so as to shed water during heavy rains. The top should be made so that it does not absorb too much water in the rainy season. The pile may be built up by spreading the manure in layers, the older at the bottom and the fresh one at the top. This will usually ensure the pile being moist and not too dry.

At times pits have been recommended for the storage of manure. These may be either *kutcha* or *pucca.* The *pucca* is to be recommended wherever possible as it prevents leaching and therefore the loss of the manurial elements due to percolation. The pits are usually rectangular in shape and should be covered if possible.

Farm manure is usually applied at the rate of ten to fifteen cart loads per acre, a cart load weighing approximately 15 maunds However a great deal depends upon the quality of the manure and the kind of crop to be grown. It should be applied uniformly over the whole field.

If an insufficient quantity of manure is available it is better to add a smaller quantity per acre and cover a larger area rather than spread it thickly on a smaller area. This practice results in a more economical use of the manure. The general practice is to apply manure once in three years by rotation.

GREEN MANURES

Sometimes it is not possible to obtain sufficient of animal manure to apply to the soil, in which case the practice of green-manuring is to be recommended. This consists in growing of quick-maturing crops, preferably legumes, and ploughing them under to be incorporated with the soil for the purpose of increasing the amount of organic matter in the soil. This improves the physical, chemical and biological condition of the soil. It should be pointed out here that most of the soils in India are lacking in organic matter, and can therefore be greatly improved by the addition of green manures. A crop suitable for green-manuring should possess these characteristics : (1) rapid growth, (2) succulence, (3) abundant foliage, and (4) ability to grow on poor soils. Most of

the plants used in this country for green manuring are legumes, although non-legumes, such as *bhang* and *rai* may be used for this purpose. The reason leguminous plants are usually preferred to non-legumes for green-manuring, is that the former are able to fix atmospheric nitrogen in the soil with the aid of symbiotic bacteria which are usually located at the nodular formations on the roots of legumes. The most common green manuring crops in this country are the following :—

Sann-hemp	...	...	(*Crotolaria juncea*).
Guara	...	...	(*Cyamopsis psoralioides*).
Dhanchia	...	...	(*Sesbania aculeata*).
Senji	...	...	(*Melilotus parviflora*).
Cowpea	...	...	(*Vigna sinensis*).
Soybean	...	...	(*Glycine soja*).

Of these, sann-hemp has been well tested by the agricultural departments and is widely recommended. It is probably the most outstanding green manure crop in India. Next in importance are *guara* and *dhanchia* the former being mostly grown in northern India, whereas the latter is largely confined to Bengal, Assam, Bihar and Madras.

These crops are usually ploughed under while they are still succulent, before the stems begin to harden. The usual practice in the case of sunn-hemp is to make the plants lie flat on the ground by planking, when they are about two or three feet high, and then turn them under by means of a mould-board plough. An acre of sann-hemp will usually yield from 350 to 400 maunds of green matter. If ·31 per cent is taken as an average amount of nitrogen, the amount of nitrogen per acre added to the soil is about one maund or approximately eighty pounds.

This practice of green-manuring produces three desirable results in the soil. Firstly, it increases the nitrogen content of the soil, especially if the crop is an inocculated legume; secondly, it improves the physical condition of the soil; and thirdly, it supplies additional organic matter to the soil. The effects of all these on the next crop are usually very marked.

CHEMICAL FERTILIZERS

Farm manures do not always completely meet the needs of the soil, especially under modern methods of intensive cultivation. Farm manure also is not balanced in composition as regards the three important plant food constituents, namely nitrogen, phosphorus and potash. The amount available is also insufficient to meet the annual losses through the removal of crops. Hence it is sometimes necessary to use substances known as chemical or commercial fertilizers. Chemical fertilizers also possess certain advantages over the farm manures, in that the former are not so bulky and may also be applied in definite proportions, according to the requirements of the crops. Some chemical fertilizers are also readily available to the crop. For most money crops, therefore, farm manure may be supplemented with chemical fertilizers.

Chemical fertilizers are usually classified according to whether they contain one or the other of the important plant food constituents. They are therefore known as: (a) nitrogenous fertilizers, (b) phosphatic fertilizers, (c) potassic fertilizers, and (d) calcareous fertilizers.

NITROGENOUS FERTILIZER

The nitrogenous fertilizers are so called because they contain available nitrogen in large quantities. The influences of nitrogen on crop growth are many: (1) it encourages the development of foliage, (2) it imparts a deep green colour to the leaves, (3) in the case of cereals, it tends to produce plumpness in the seeds, and (4) it tends to produce succulence or tenderness in the plant, a character which is desirable in certain crops. However if improperly used in large quantities nitrogen may produce the following harmful effects on the crop: (1) it may lower the quality of the crop, (2) it may delay maturity, (3) it may decrease resistance to disease, and (4) it may weaken the stems and cause lodging in cereals.

Some of the most common nitrogenous fertilizers which have been tried out in this country are the following:

1. Sodium Nitrate—Na NO_3.
2. Ammonium sulphate—$(NH_4)_2$ SO_4.

3. Calcium cyanamide (Ca CN_2).
4. Cotton seed meal.
5. Linseed meal or cake.
6. Mustard cake.
7. Castor cake or castor pomace.
8. *Neem (Melia azidirachta)* cake.
9. Groundnut cake.
10. *Mohwa (Bassia latifolia)* cake.
11. *Til (Sesamum indicum)* cake.
12. Poppy cake.
13. *Kusum* cake (Safflower cake).

Sodium nitrate as it comes on the market is a yellowish white crystalline substance, very soluble in water and very readily absorbing moisture from the air. When applied to the soil, it diffuses very rapidly and is immediately available to plants. This fertilizer is applied to the crop at the rate of 100 to 300 lbs. per acre, depending upon the kind of crop and the nature of the soil. Sodium nitrate, however, leaves an alkaline residue in the soil. This is probably due to the absorption of the sodium by the soil and the releasing of the nitrate ions which are generally lost by leaching or used up by the plants. Thus the effect of large applications of sodium nitrate over a series of years is to produce a poor tilth in some soils due to the deflocculating action of sodium. This condition may be prevented by applying sodium nitrate and ammonium sulphate alternately, since the latter leaves an acid residue which will neutralize the alkaline reaction in the soil. In regions where there is a tendency towards the development of soil alkali, this fertilizer should be used judiciously.

Ammonium sulphate is a by-product from the production of coke and illuminating gas from coal. As it appears on the market, it is in the form of greyish or greenish coloured crystals. In commercial forms it contains about 25% of ammonia or 20 per cent of nitrogen. Ammonium sulphate is also very soluble in water. When applied to the crop, the ammonia has to be converted into nitrate with the help of certain nitrifying bacteria. For this reason it is not as readily available as the nitrate of soda, although certain crops like rice may

be able to use the ammonium nitrogen without conversion to nitrate nitrogen. But this transformation is quite rapid so that the ammonium sulphate may be considered to be almost as quickly available to the plant as the nitrate of soda, and may therefore be applied to such rapid growing crops as sugar cane, where nitrogen is found to be deficient. Unlike nitrate of soda, this fertilizer leaves an acid residue in the soil. This is believed to be due to the absorption of ammonia by the soil or the plant and the consequent accumulation of the sulphate ions. This fertilizer, therefore, is more especially applied on land which has a more or less alkaline reaction. Or, as suggested in the preceding paragraph, it may be applied alternately with sodium nitrate. On the other hand this fertilizer should not be mixed with such alkaline fertilizing materials as wood-ashes, basic-slag, potassium carbonate, and lime, as the combination with any of them will liberate the ammonia in the ammonium sulphate, and thereby decrease its value as a fertilzer.

Experiments carried out in different parts of India seem to show that ammonium sulphate is more effective than the nitrate of soda, as a source of nitrogen. The fertilizer has been extensively applied for such crops as wheat, rice, sugar cane and potatoes. And even in certain acid soils in Assam, the application of ammonium sulphate at the rate of 160 lbs. per acre has given the best yields of tea.

Calcium cyanamide is found on the market as a black crystalline powder and is very light in weight. It is a product made possible by the development of electricity. It contains about 20 per cent of ammonia. It is not very readily available to plants and undergoes some very complex changes in the soil. It is believed that ultimately urea is produced. As these changes take place toxic compounds are also produced. Evidently it is a slow acting fertilizer, and therefore should be applied some time before the crop is sown

Experiments in India so far have shown no distinct advantage in the use of this fertilizer.

There are materials besides these three mentioned above which are carriers of nitrogen and have been used extensively in other countries but so far their use in India is very limited. Some of the substances used are basic calcium nitrate, potassium nitrate, and ammonium nitrate. The first of these three occurs naturally in many parts of

India but most of the product is exported to other countries for use in the manufacture of gun powder.

PHOSPHATIC FERTILIZERS.

Phosphatic fertilizers are those which are carriers of phosphorus. This element is also very essential for plant growth, and in some soils it may be found to be lacking; hence the need for the application of a phosphatic fertilizer. The functions of phosphorus in the plant are various, namely: (1) it hastens the maturity of the crop, (2) it encourages root development, (3) it decre ses the ratio of straw to grain in cereals, (4) it strengthens the stems and thereby reduces the tendency to lodge in cereals, (5) it sometimes increases resistance to disease, and (6) in some cases, it improves the quality of the crop. Unlike nitrogen, phosphorus if applied in excessive quantities generally produces no bad effect on the crop. On the other hand, the lack is not usually apparent to the eye, from the colour of the plant, as in the case of nitrogen, so that a phosphorus deficiency may occur and not be easily detected. One of the important functions of phosphorus is to balance or off-set the harmful effects of excessive nitrogen.

The most common phosphatic fertilizers are superphosphate, basic-slag and bone phosphate.

Superhosphate [$Ca\,H_4\,(PO_4)_2$] is one of the earliest substances used as a fertilizer, the process of manufacture having been invented by Sir John Lawes of the Rothamsted Experiment Station in 1843. It is made by treating ground rock phosphate or any material which contains a large percentage of the tricalcic or bone phosphate, with sulphuric acid. The object is to render the phosphate more soluble. The term superphosphate is thus generally applied to any material containing as its chief constituent soluble phosphoric acid, whereas a phosphate is one which contains phosphoric acid as its chief constituent. Superphosphate occurs on the market as a brownish grey powder. It is partially soluble in water and gives an acid reaction to litmus paper. But the fertilizer on the whole does not impart an acid reaction to the soil, but on the other hand, it has a slight neutralizing effect by making aluminium and iron insoluble. This fertilizer is sometimes known as an "acid phosphate."

Basic Slag [$(CaO)_5 P_2 O_5 SiO_2$] is a by-product of the manufacture of steel from ores containing phosphorus and contains a large amount of iron and calcium hydroxides. It is heavy dark grey powder and is extremely alkaline to litmus. It contains from 14 to 20 per cent of phosphoric acid. The phosphorus of this fertilizer is practically all soluble in citric acid and is therefore considered as available phosphoric acid. When applied to the soil it becomes almost immediately available, but is not considered to be as readily available as superphosphate.

Superphosphate when applied alone has been found to be beneficial for sugarcane in Gaya (Bihar) and rice in Manganallur (Madras Presidency).

POTASSIC FERTILIZERS

Potassic fertilizers are those that contain potash as their chief constituent. Potassium like nitrogen and phosphorus is also a very essential element for crop growth. This element may also be found to be in insufficient quantities in the soil for proper plant development. Hence the addition of a potassic fertilizer may sometimes be found necessary. The different functions of potash on the plant are: (1) it help the transference of food materials from one part of the plant to another, (2) it is necessary for the development of the chlorophyll or green colouring matter in the plant, (3) it tends to increase plumpness in grains, and (4) it tends to have a balancing effect between the phosphatic and nitrogenous fertilizer material. Like phosphorus its presence in large quantities in the soil produces no detrimental effect on the crop.

The most common potassic fertilizer materials are the sulphate of potash, chloride of potash, potassium nitrate, wood-ashes, leaf-mould or garden compost, water hyacinth, garden weeds and the like.

Potassium Sulphate (K_2SO_4) and **potassium chloride** (KCL) also sometimes known as the muriate of potash are the two most common sources of potassium for manurial purposes. Both these products generally occur together naturally in France and Germany and are then known as kainit. These substances are immediately soluble in water and diffuse very readily in the soil, where they are absorbed by colloidal substances. The sulphate was one of the earliest fertilizers used

for its potash, but muriate is becoming more and more popular as it has been found to be more effective. Both these fertilizers have a tendency to leave an acid residue in the soil.

An application of these fertilizers in this country has not met with success, except in a very few cases. The experiments in Bombay with these fertilizers indicate that they are beneficial only for chillies and tobacco. In the Punjab, experiments on potassic fertilizers have resulted in financial loss. The experiments conducted at Meerut and Cawnpore on the value of the application of potassic fertilizers on wheat indicate that the crop is not benefited by the application of this fertilizer. And even in Sambalpur (Orissa) where the soil is reported to be lacking in potash the application of these fertilizers has not appreciably increased the yield of rice.

Other sources of potash which may be increasingly used in this country are wood-ashes, leaf-mould, garden weeds, water-hyacinth, etc. Wood-ashes generally contain from 5 to 6 per cent of potash in the form of potassium carbonate, which is alkaline in reaction. The potash obtained from these sources is even more desirable than from that of chemical fertilizers, in that the former do not leave an acid residue in the soil.

CALCAREOUS MANURES

Calcareous manures are those which are rich in calcium, or calcium and magnesium. Calcareous manures, however, were not generally considered as fertilizers because it was believed that they were not plant foods, but only soil amendments, or substances which modify the physical condition of the soil. This distinction however is not generally held at present, as calcium is also an essential food element for the plant. Among the most common calcareous manures are lime in its different forms and gypsum. The application of lime to Indian soils is very limited, being restricted to the correction of soil acidity or the improvement in the structure and tilth of clay soils. Gypsum is sometimes used for the correction of soil alkalinity in the presence of sodium carbonate. The application of lime in this country has not proved beneficial to crops, probably because soils in this country, especially the alluvial soils of the Indo Gangetic plain contain the element of calcium in sufficient quantities for crop production. Even with the

acid soils in Assam, experiments carried out in the Tocklai Experiment Station indicate that no advantage has resulted from the application of lime. The use of gypsum for the correction of soil alkalinity is limited because of the high cost of this material. But where it can be had at a low cost, the material may be used more profitably in the conversion of sodium carbonate into sodium sulphate which is a salt less injurious to plants than the carbonate.

ORGANIC MANURES

There is another class of substances generally known as "cakes" and their use in India as fertilizers is growing in popularity. The following are some of those commonly used in this country : (1) castor cake or pomace, (2) cotton seed meal, (3) mustard cake, (4) linseed cake, (5) *neem* cake, (6) groundnut cake, (7) *mohwa* cake, (8) *til* cake, (9) poppy cake and (10) *kusum* cake.

Experiments in India with these cakes generally indicate a definite advantage in their use as fertilizers. In general, their value compares favourably with animal manure. In Madras, oil-cakes have been found beneficial for sugar cane and rice and their more extensive use is advocated. In Bombay, oil-cakes have been found to be good in all cases and particularly for such crops as sugar cane, rice and tobacco. Punjab experiments indicate that castor and *mohwa* cakes do not give as good results as mustard (*toria*) cake. In the United Provinces, oil-cakes are used even more extensively than in the other provinces, and for various crops While mustard cake and also linseed cake may be used as fertilizers, the practice is not to be recommended because these are generally fed to animals and are therefore more expensive. How ever if the urine and droppings from the animals thus fed with these substances are properly conserved, much of the nitrogen in these fertilizers will ultimately reach the soil.

The non-edible oil cake like *neem*. *mahwa* and castor should be the ones to be extensively used for manurial purposes. While poppy and safflower (*kusum*) cakes have been found to give a large increase in yield, yet these cannot be used extensively as they are available in small quantities only. The application of oil cakes in the United Provinces has been found to be advantageous for such crops as potatoes, sugar cane, wheat and rice.

The amount of oil-cake to be applied to the soil varies with the soil in different localities but an application of 300 to 400 pounds per acre may be considered as an average. One point in favour of the application of oil-cakes is that no detrimental effect is known to result from their application.

From the national standpoint a large export of oil seeds to foreign countries should be discouraged as this would rob the country of the fertilizing materials which the soil needs so badly. The Board of Agriculture also made reference to this point as early as 1919. The oil may be exported after it has been extracted thus allowing the oil-cakes to be fully available for manurial purposes.

Bone phosphate.—Bones are the chief source of phosphates that exist in combination with organic matter and were for a long time the main source of phosphorus for manurial purposes. In India, bone phosphates are available in two forms: bone meal and bone-char. *Bone meal* as it comes on the market is a dusty powder possessing a characteristic odour. It contains about 27 per cent. of phosphoric acid. Bone-meal is slow in its action and is therefore not immediately available to the crop. However its availability is dependent to a large extent on the fineness of the substance when applied to the soil. In the soil it is slowly converted, in the presence of water, into a soluble monocalcium phosphate which becomes available to the crop.

Bone-char is usually made by lightly firing the bones so as just to-char or blacken them throughout their thickness. This makes them brittle and porous and easily crushed to powder. In this form the phosphoric acid, for which this material is applied to the soil, becomes more quickly available to the crops. Although about 50 per cent. of the nitrogen is lost in the process of charring, nearly all of the phosphoric acid is preserved. Bones of cattle and other animals can always be easily had around the villages in India, and are probably the cheapest source of phosphates for crops. The process of charring can easily be carried out on the farm and does not require any skill.

In connection with phosphatic fertilizers, experiments in India on the whole indicate that most soils in this country are not lacking in phosphorus. However there are a few areas in which the addition of phosphatic fertilizers such as bone meal or superphosphate, which has

been found to be beneficial in increasing the yield of crops. Experiments at Pusa show that the soil of that area can profitably be improved by the addition of bone meal in the production of such crops as potatoes, gram, oats or wheat. Experiments at the Aduthurai farm indicate that the soils of the Tanjore delta in the Madras Presidency are generally deficient in phosphates and therefore would probably be benefited by the application of phosphatic manures. The soils of the Assam valley on the other hand, though found lacking in phosphates, have not been benefited by the application of bone-meal.

Bone meal alone, has also been found to be beneficial for rice in Bombay and Bihar. In the United Provinces the only experiment which shows an increase in yield due to the application of bone meal, is the one reported from Partabgarh on rice.

Poudrette, a material which consists largely of night soil (human excreta) and which is sometimes available near large cities and towns, is one of the most valuable form of fertilizer, as it is rich in nitrogen and all the necessary elements for plant growth. Experiments carried out in different parts of India with this form of fertilizer have shown that large increases in yields of crops are obtained by its application. The experiments at Cawnpore, in the United Provinces, with (poudrette have shown that the yields of potatoes, sugar cane and maize were nearly doubled. Experiments carried out at the Arbhavi and Dharwar farms in the Bombay Presidency for a series of years have shown that this form of fertilizer is very suitable for such crops as sugar cane, maize, *jowar* and cotton.

Municipal sweepings are another source of organic manure which can be had near cities and large towns. This is a heterogenous material which consist of vegetable wastes, rags, papers, droppings from animals, leather, hair, factory wastes, etc.

A compost is a material generally made of alternate layers of manure and vegetable or other organic matter. The manure supplies the organism which help to decompose the mass through their biological activities. For the proper functioning of these organisms, the mass should be kept moist. This moistening also helps to retain the ammonia evolved in it. In making *compost on the farm,* the following materials are usually made use of : (1) the farm wastes, which may consist of grasses and weeds of all kinds, crop residues, etc. (2) the

cow dung, (3) the litter and sweepings from the cattle sheds, and (4) wood-ashes. *A Municipal compost* is made of alternate layers of municipal wastes and night-soil, which is then allowed to ferment and decay, until the foul odour is considerably reduced. This material generally becomes ready in about three months from the time the making of the compost is begun. Both of these composts are rich in plant food constituents. Results of experiments in this country seem to show that the latter, that is the municipal compost, is even richer than the former in those food elements necessary for plant growth.

MIXED FERTILIZERS.

Under the term mixed fertilizers the following fertilizing materials that have been tried in this country, may be mentioned :

(1) Niciphos,
(2) Leunaphos,
(3) Diamminophos,
(4) Nitrophoska,
(5) Nitrochalk,
(6) Sennaphos, etc.

These are mixtures of materials containing phosphorus and nitrogen in some one of their available forms. Ammophos, for instance is a mixture of materials, containing ammonia and phosphates mixed in certain proportions. These names are only trade names and do not therefore signify any definite chemical composition. For instance, Ammophos as sold in the Indian market is found in the following ratios: 13/48 and 20/20. While the mixing of fertilizer is very advisable in cases where soils are known to be lacking in more than one of the essential elements, the soil conditions in India are such that in the majority of cases, the addition of phosphates is unnecessary and therefore the application of ammophos, for instance, may mean a waste of the phosphate-bearing material. It would be more economical in such cases to add more of the nitrogen-bearing material. This is undoubtedly one of the disadvantages of a mixed manure. On the other hand, soils which are deficient in both nitrogen and phosphorus, could be greately benefited by the application of such a mixed fertilizer. The rice crop in certain parts of Bihar and Orissa has been found to be benefited by the application of phosphatic fertilizers. In such soils the application of a fertilizer carrying both the elements, nitrogen and phosphorus, may be found useful.

As to whether the application of a certain fertilizer will be profitable or otherwise is not an easy matter to decide. The only way of finding out is to apply a particular fertilizer to the soil in question. This may be tried in a small area. Before doing this, a farmer would be well advised if he would first consult the local authorities of the agricultural department.

The maximum profit to be derived from the application of manures and fertilizers depends to a large extent on various factors such as soil, the price of the fertilizer, the kind of crop for which the fertilizer is being applied, the climate, the system of c opping, the price obtained for the crop produced and various other factors. The amount of fertilizer applied should therefore be determined largely by local conditions. And, as the price of chemical fertilizers in this country is rather high, and the priecs obtained for the crop produced are generally very low, it is probably more advisable in most cases not to apply large amounts of these fertilizers.

At the present time a great number of investigations regarding the utility or otherwise of the various fertilizers in question are being carried on ; so it is hoped that as time goes on more definite information will be available on this question of fertilizers.

EVALUATION OF MANURES

The value of farmyard manure and other kinds of manures produced or obtained on the farm depends on several factors, such as the kind of manure, the method of storing, the manurial ingredients contained in them and also the amount of supply. But farmyard manure cannot be properly evaluated because of the fact that it not only supplies certain manurial ingredients to the soil but it also more or less improves the structure of the soil, which improvement cannot be easily measured. Commercial fertilizers on the other hand are usually bought for the amount of those fertilizing ingredients which they contain, and their values can therefore be compared with one another.

Supposing, for instance that the price of ammonium sulphate, containing 20 per cent of nitrogen is quoted at Rs. 4-8-0 per maund. This means, therefore, that the price of $\frac{20}{100}$ of 1 maund or 8 seers of nitrogen is Rs 4-8-0. That is, the price of 1 seer of nitrogen in ammonium sulphate is nine annas.

Taking the price of nitrogen in the ammonium sulphate as a standard, the value of castor cake may be calculated in this way.

Since castor cake contains 5% of nitrogen, one maund of castor cake therefore will contain about 2 seers of nitrogen. Its value will therefore be (9 × 2) or Re. 1-2-0. Castor cake also contains about 2½ per cent of P_2O_5. If its value is considered to be half that of nitrogen, then the value of a seer of phosphoric acid contained in a maund of castor cake will be Re. 0-4-6. Therefore, the value of these ingredients in a maund of castor cake is Rs. 1-6-6. The potash contained in the cake may be considered to be of no value, as most Indian soils are not lacking in it. However, the cake contains organic matter which has some value in improving the structure of the soil. If this is priced at 3 annas a maund, the total value of castor cake will be about Re. 1-9-6 per maund.

This valuation of animal manures and oil-cakes does not give the real agricultural value, as it is difficult to estimate the residual effects and consequent improvement in various ways in the soil.

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CHAPTER X.

WEEDS

Weeds constitute an important problem in agriculture. The losses due to weeds, although generally recognized, are often far greater than are usually realized. The presence of weeds directly and indirectly reduces the yield of crops, for they not only directly rob the crops of their plant food and water, but they also occupy the space where crop plants may grow, or by competing with crops for sunlight, and moisture, considerably affect the yield of crops. Weeds also frequently harbour insect pests and fungous diseases which later attack the crop. The cost of removing weeds also adds to the cost of production and consequently reduces profits. It therefore becomes desirable for one to know how to control weeds in order to get the maximum profits from the crop. However, the subject of weed control has not had the attention it deserves from agricultural scientists in this country, so that methods of weed control have not been thoroughly worked out.

A weed may be defined as being any plant growing out of place. That is, even a crop plant may become a weed if it grows in places where it is not wanted. A plant becomes a weed because of its persistence in growing amongst crop plants. This aggressive character of weeds is due largely to several factors such as their methods of propagation, habits of growth, and hardiness.

Weeds propagate themselves in various ways. They may either reproduce themselves vegetatively, that is by roots, tuber, bulbs, pieces of stems; or sexually by means of seeds. Thus some of the most troublesome weeds like *doob*, *kans*, and *motha* propagate largely by means of their underground stems, whereas the bind weed propagate largely by means of its roots. On the other hand, most plants like *bathua* and *chaurai* spread very rapidly because of the large number of seeds produced in each plant. It is therefore very important for one to know the general life-history of each plant in order to be able to combat them judiciously.

The control measures that have so far been adopted for combating weeds may be grouped as follows:

1. Preventive measures:
    (1) Use of pure seeds.
    (2) Clean cultivation.
    (3) Use of irrigation water free from weed seeds.
2. Remedial measures:
    (1) Biological.
    (2) Chemical.
    (3) Mechanical.

Preventive Measure.

1. *Use of pure seeds.*—One of the important ways by which weeds are introduced into cultivated fields is by the use of impure seeds. This can be prevented by the use of pure seeds that is, by sowing crop seeds which do not contain weed seeds. In this connection it may be pointed out that countries like America have special laws against the sale of impure seeds and officers whose main duty is to test crop seeds and certify their purity. No seeds are allowed to be sold for sowing purposes which have not been certified by seed-testing officers. Some of our most troublesome weeds have been introduced not only from different parts of India but also from foreign countries.

2. *Clean cultivation.*—The spread of weeds may also be discouraged by clean cultivation, which consists in the removal of all weeds by various ways such as pulling, hoeing and cultivating. Boundaries of fields, corners, waste places, irrigation channels and road-sides, all should be kept clean of weeds, so that they are not allowed to produce seeds. After a crop is harvested any weeds growing at that time should be removed so that they do not produce seeds for the next year's crop.

3. *Use of irrigation water free from weed seeds.*—Another very common way by which weed seeds are introduced into an irrigated farm is through irrigation water. When the irrigation channels lie unused, weeds growing along their banks drop their seeds in the channels; consequently when the first water comes along, it washes the seeds into the fields where this water is applied. In canal colonies one

should take care not to use the first water in the fields for the simple reason that it usually contains a great number of weed seeds. In sewage irrigated farms also, weed seeds find their way into the sewage irrigation water from various sources, such as kitchen wastes and undigested seeds and seeds from sweepings and rubbish, and they ultimately find their way into the fields.

Remedial Measures.

1. *Biological.*—It is a well-known fact that certain crops are almost completely destroyed by certain diseases and pests. This knowledge is made use of in some places in the attempt to eradicate certain of the most serious weeds. That is, certain fungous diseases or insect pests which are known to attack and destroy such weeds are propagated and then liberated in places where those weeds are found to be serious. In some cases good results have been reported. However this method is quite new and has not been used to any extent in this country. As an example of what can be done in the control of weeds by such methods, the work carried on in Madras and Bombay in connection with the eradication of certain species of cactus with cochineal insects may be cited. These insects which belong to a genus of mealy bugs protect themselves with a covering of a waxy substance. It has been reported that these insects feed on *Opuntia elatior*, a species of cactus and ultimately destroy it. In a work of this kind it is necessary that expert supervision and guidance be obtained, as otherwise it may prove disastrous to crop plants which may be attacked by the same disease or insect. This method therefore cannot be adopted by farmers, but is one that Governments can take up.

2. *Chemical.*—The use of chemical compounds in the eradication of weeds is becoming more and more common. Some of the most common chemicals used in the control of weeds are copper sulphate and sodium arsenite. Some others of less importance are iron sulphate, sulphuric acid, carbolic acid, sodium chloride, and ammonium salts. The strength of the solution depends on several factors, and it has therefore to be found out by actual field trials on the particular weeds which are to be eradicated.

The method of application is also dependent on the character of the chemical as well as of the plants on which it is to be used. Materials such as copper sulphate or sodium arsenite may be used in the form of a liquid spray or in the form of dust. In either case application is usually made by the aid of a machine. Care should be taken that live-stock are not allowed to come to the fields where such chemicals are used, as these substances are poisonous

The use of chemical substances as weed killers is still in an experimental stage in this country and has not as yet been extensively adopted as it is rather expensive.

3. *Mechanical.*—Some of the mechanical means by which weeds may be controlled or eradicated are ploughing, sometimes with special types of ploughs, cultivating, harrowing or using the *bakhar*, mowing, hoeing, and pulling. These are the methods now commonly used, although they also involve a great deal of labour and expense.

Some of the most common weeds

It is not possible to give a complete list of weeds, hence only a few of the more obnoxious and widely distributed are discussed in this chapter.

Weeds may be classified in various ways, but in this country they are often referred to as *kharif* and *rabi* weeds depending upon the crop with which they are associated. The life-history, distribution and control measures of some of the most common and troublesome weeds are given below.

KHARIF WEEDS.

1. **Cynodon dactylon** Pers.—(Hindustani : *doob*).—*Doob* or *hariali*, a member of the grass family, is one of the most common weeds on the farms in this country. It is found all over India from Cape Comorin to Kashmir. In the south it is generally known as *hariali* grass, while in north India it is commonly known as *doob.* While this weed is most troublesome in cultivated fields, it is also one of the most valuable of pasture or fodder grasses in most parts of India, and is also used extensively for lawns, and as a soil binding plant for *bunds* in order to prevent erosion. This grass is commonly

found in good soils, and will not grow well in the shade. It is a very hardy plant, much-branched, fairly leafy and possesses numerous underground stems. The above-ground branches may be erect or prostrate which later often develop roots at the nodes. This grass usually grows in patches forming, when thick, a mat-like appearance on the surface of the soil. It has been noted that this grass is peculiarly subject to a type of smut.

It is very difficult to eradicate this grass by ploughing, as bits of the stems that are broken by the plough may be buried and produce new plants. For this reason the mould-board plough is preferred to the *desi*, as the former generally does not break the stems up into small pieces but loosens clumps which can be removed. However the soil infested with this grass should not be ploughed too deep as the broken portions of the stems are apt to be buried deeper in the ground. After ploughing the uprooted grass should be removed either by hand or by harrows.

Land badly infested with this grass, if planted to *jowar*, wheat or any dense growing crop, for a year, or two, will be more or less free from this grass, as it is smothered out by such crops.

2. **Saccharum spontaneum** L. (Hindustani: *kans*).—This is another member of the grass family and is also very commonly distributed all over India. It is a tall perennial grass with a creeping root stock. The stems are usually erect and grow to a height of about 4 to 6 feet. The grass propagates itself by means of the underground creeping stems or rhizomes and also by seeds carried by the wind. The grass is not altogether useless as it is sometimes used in thatching, the stems are also used for making country pens, and the grass is sometimes grown on banks of channels and *bunds* in order to prevent erosion. More recently it has been used as a parental stock for the improvement of sugar cane varieties in India.

This weed may be controlled by deep ploughing, followed by harrowing in order to remove the uprooted stems. Or it may be controlled by frequent cultivation of the soil. There have been developed special ploughs in various parts of the country for the purpose of eradicating this very troublesome weed. Wherever this weed occurs, care should be taken not to allow it to produce seed, as the fields may again become contaminated with *kans*.

3. **Eragrostis cynosuroides**, Beauv. (Hindustani: *kus* or *kussa*).—*Kus* or *kussa* is also another member of the grass family. It is a perennial grass with stout and creeping root stocks. It is very common throughout the plains of India and in the Deccan. It grows in all kinds of soils including the low-lying *usar* lands of the plains. The stems are more or less erect and grow to a height of 1 to 3 feet. This grass is also not altogether useless as it produces fibre which is used for making ropes.

The usual method of eradicating this grass is by ploughing the land with a mould-board plough as deep as possible. The land is then harrowed in order to remove the uprooted rhizomes. This method should be repeated several times until the fields are free from this weed.

4. **Cyperus rotundus**, Linn. (Hindustani : *motha*).—This plant, although it is similar in appearance to grasses is botanically not a grass but a member of the *Cyperaceae* or the family of sedges. The common English name for it is *nut grass*. It is so called on account of its grass-like appearance and also because of the nut-like underground stolons which it possesses. It is a perennial, but it thrives during the rainy season, or whenever there is sufficient moisture for its growth. Unlike the grasses, *motha* has a triangular stem and possesses three-ranked leaves and can therefore be easily distinguished from other grasses which possess round stems and alternate or two-ranked leaves. The plant usually possesses a single stem.

The plant reproduces itself in two ways, by means of seeds and by the underground stolons or tubers. These tubers contain stored food material which enables them to produce new plants. The tubers are also quite resistant to extremes of temperatures and to drought thus rendering this plant quite hardy and therefore very troublesome to eradicate. The depth at which these tubers occur in the soil depends much on the nature of the soil and the amount of moisture it contains. In moist heavy soils they are usually found near the surface, while in dry sandy soils they occur at greater depths, even two feet or more.

This is one of the most difficult weeds to eradicate, as it reproduces both by the tubers and by seeds. The tubers are very numerous and small in size, making their removal extremely difficult. Deep ploughing in the case of this weed is not very effective in eradicating it, as it

simply digs up the soil and buries the tubers deeper. Clean and frequent cultivation, which will deplete the stored food in the tubers, thus slowly starving the plant to death, mày be adopted as one of the control measures.

This weed also spreads itself rapidly by seeds. So every effort should be made not to allow the plants to mature and produce seeds. One of the easiest way to check seed production is by cutting the aerial shoots before flowering by sickles or other means, if clean cultivation is impracticable.

In some countries spraying with sodium arsenite has been tried with some success in the control of this weed. But under Indian conditions this method may not be economical.

5. **Tribulus terrestris**, Linn. (Hindustani : *gugru*).—This plant is a member of *Zygophyllaceae* or the caltrop family. It is a native of the Mediterranean regions and has therefore been introduced into this country. It is a low, trailing, annual plant, much-branched with hairy stems which spread on the ground in all directions to a distance of about four to six feet from the centre. It is common almost throughout India, ascending the Himalayas up to a height of about 11,000 feet.

It propagates itself by means of seeds contained in fruits which possess sharp spines. These spines help the dispersal of the seeds by sticking to objects which may come in contact with them. For instance, they may stick to the rubber tyres of cycles, motor cars and aeroplanes and in this way be carried long distances. The sharp spines, however, sometimes puncture the tyres, whence this plant got its popular name of puncture vine in the United States of America.

The young leaves and stems of this plant are sometimes used as pot-herbs or greens, and other parts of the plant are claimed to possess some medicinal value.

The weed may be controlled by removing the plants before the development of fruits, as each plant is able to produce from ten to twenty thousand seeds.

6. **Trianthema monogyna**, Linn. (Hindustani : *pathri*).—This plant is a member of the *Aizoaceae* or carpet weed family. It is common throughout India. It constitutes one of the most conspicuous and aggressive weeds of cultivated fields, While it grows in all kinds

of soils, it thrives best on rich lands, and if not controlled prevents the growth of crops. The plant is pro-cumbent and trailing in habit producing a mat-like growth. The stems are succulent. The plant propagates by means of black seeds which are contained in a sac-like structure at the axil of the petiole of the leaf.

The best method to control this weed is not to allow the plant to produce seeds. It should therefore be destroyed before it reaches maturity. Mature plants should not be fed to cattle as the seeds of this plant pass through the digestive tract of an animal without being digested. This weed cannot be controlled by a smothering crop.

RABI WEEDS

1. **Chenopodium album**, Linn. (Hindustani: *bathua*).—This plant is a member of the *Chenopodiaceae* or "goose-foot" family. The weed is one of the most troublesome in wheat fields as well as in the vegetable gardens throughout northern India. The plant is either erect or ascending, growing in the plains of India to a height of one to three feet. It is sometimes used as a pot-herb.

The plant is best controlled by not allowing it to produce seeds. It should therefore be cut or removed before it is mature. When cutting, one should be careful to cut the plants below the ground as otherwise they may sprout again. If the plants have reached maturity they should not be fed to cattle as the seeds usually pass through undigested and ultimately reach the fields along with the manure.

2. **Argemone Mexicana**, Linn. (Hindustani: *leh*).—This plant is a member of the *Papavaraceae* or the poppy family. It is a native of America and has been introduced into this country. It is now commonly found all over India. It grows along roadsides and in waste places, but is also common in cultivated fields particularly in *barani* lands. The plant is a spiny, herbaceous annual, stands erect and varies in height from 2½ to 4 feet approximately. The flowers are bright yellow and the leaves are lobed and very prickly. Its juice is also yellow. The seeds are borne in bristly capsules which, when mature, break open and disclose a great number of seeds Each plant is able to produce from 20,000 to 30,000 seeds.

The weed may be controlled by removing the plants when young and not permitting them to produce seeds.

3. Convolvulus arvensis, Linn. (Hindustani: *chandvel*).—This plant is a member of *Convolvulaceae* or the morning glory family. It is also very common in cultivated fields almost throughout India. It is a very troublesome weed almost throughout the temperate and sub-tropical regions of the world.

The plant is a perennial and possesses fleshy root-stocks which produce slender stems which twine around other plants. Hence the plant is more commonly known as a bind weed. Its deep-rooting habit makes it very hardy and by twining it chokes out crop plants. It propagates itself by seed as well as by root-cuttings.

The weed is very difficult to eradicate as any portion of the root-stock is able to produce a new plant. It may be controlled by practising clean cultivation for one season and thereby starving out the root-stocks.

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PRINCIPLES AND PRACTICES

OF

CROP PRODUCTION IN INDIA

PART II

FIELD CROPS

BY

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CHAPTER XI

DISTRIBUTION AND ECONOMIC IMPORTANCE OF FIELD CROPS

Indian agriculture consists mainly of the production of crops. These are of three kinds. First in importance are the field crops; second are the vegetable crops; and the third, the fruit crops. Of these three, the first is by far the most important in this country, as the area occupied by field crops is very much greater and the total production is also many times greater than that of the other two kinds.

Of the field crops grown in this country, rice occupies by far the largest area. The other important field crops grown in this country are given in the following table which gives the acreage during the four year period from 1930 to 1934.

TABLE XX

Statistic of area in acres under principal crops in India.

Name of crop.	1930-1931.	1931-1932.	1932-1933.	1933-1934.
Rice	82,846,007	84,374,000	82,882,000	83,042,000
Wheat	32,169,000	33,803,000	32,976,000	35,992,000
Sugarcane	2,801,000	2,971,000	3,317,000	3,311,000
Cotton	23,812,000	23,722,000	22,183,000	24,137,000
Jowar	35,616,000	34,539,000	34,100,000	32,761,000
Barley	6,637,000	6,413,000	6,347,000	6,656,000
Bajra	17,524,000	18,310,000	18,699,000	16,552,000
Tobacco	1,357,000	1,279,000	1,251,000	1,227,000
Gram	15,432,000	17,935,000	15,955,000	18,653,000
Linseed	3,009,000	3,309,000	3,299,000	3,261,000
Groundnut	6,579,000	5,489,000	7,409,000	8,226,000
Maize .. .	7,059,000	6,892,000	6,948,000	6,769,000
Jute .. .	1,862,000	2,143,000	2,517,000	2,670,000
Sesamum	5,618,000	5,639,000	6,256,000	6,307,000
Mustard and rape ..	6,632,000	6,220,000	6,094,000	6,034,000
Castor	1,457,000	1,583,000	1,617,000	1,534,000

The figures in the above table show that of the important field crops rice stands easily first in the order of acreage sown under each crop, followed by wheat, *jowar*, cotton, gram, *bajra*, groundnut, etc. The figures further indicate that the production of field crops occupies a very important place in the agricultural industry in this country. The production of fruits and vegetables, as well as the raising of cattle is still of secondary importance.

The relative importance of field crops, fruits, vegetables, etc., is to a great extent indicated by the following table.

TABLE No. XXI.

Areas under the different classes of crops and percentages of the total area sown in British India and the Indian States.

Classes of crops.	Acreages in 1933-1934.	Percentage of total area sown.
Food grains	259,199,000	75·7
Fibres	24,880,000	7·3
Oilseeds	24,989,000	7·3
Fodder crops	13,293,000	3·9
Sugar	3,606,000	1·1
Condiment and Spices	1,830,000	0·5
Drugs and Narcotics	2,688,000	0 8
Dyes and tanning materials	624,000	0 2
Fruits and vegetables	5,520,000	1·6
Miscellaneous food crops	3,490,000	1·0
Miscellaneous non-food crops	2,177,000	0·6
Total	342,296,000	100·0

Table XXII

Showing the estimated value of field crops in rupees.

Name of crop	Acreage in 1933-1934	Total production in maunds	Yield per acre in maunds	Average price per maund in rupees	Estimated total value in rupees.
Rice	83,042,000	842,587,200	10·1	5·314	40,477,508,380
Wheat.. .	35,992,000	257,275,200	7·1	3·566	917,443,363
Sugar cane .	3,311,000	133,660,800	40·4	4·564	610,027,891
Cotton.. ..	24,137,000	24,917,069	1·0	23·904	595,617,617
Jowar .. .	32,761,000	169,014,300	5·2	2·614	441,803,380
Barley.. ..	6,656,000	65,820,300	9·9	2·619	172,383,365
Bajra	16,552,000	58,094,400	3·5	2·682	155,809,180
Tobacco ..	1,227,000	15,315,300	12·5	12·542	192,084,492
Gram	18,653,000	103,166,700	5·5	2·700	278,550,090
Linseed ..	3,261,000	10,264,800	3·1	5·290	54,300,792
Groundnut ..	8,226,000	90,909,000	11·1	3·000	272,727,000
Maize	6,769,000	51,979,200	7·7	2·517	130,831,646
Jute	2,670,000	9,287,803	3·5	8·172	75,899,926
Sesamum ..	6,307,000	14,769,300	2·3	7·675	113,354,377
Mustard and rape .	6,034,000	25,743,900	4·3	6·324	24,688,263
Castor . ..	1,534,000	3,903,900	2·5	..	..

Rice.—The figures in table No. 22, indicate that rice is by far the leading crop of India. It occupies about 24 per cent. of the total area sown. Its cultivation is mainly confined to the more humid regions of the country and it is therefore grown mostly in Bengal, Bihar, Orissa, Madras and parts of the United Provinces, the Central Provinces, Assam, and Bombay. It is the staple food of the people in the eastern part of the country.

India is also by far the greatest rice-producing country in the world. Its total output in 1932 was 31,114,000 tons. The following table shows the position of the principal rice growing countries in world production of rice.

TABLE XXIII

Principal rice-producing countries of the world.

Country.	Area in acres.	Production in tons in 1932
India	84,374,000	31,114,000
Japan	7,980,000	10,726,000
Indo-China	13,252,000	5,711,000
Java and Madura	9,332,000	5,305,000
Siam	7,438,000	5,065,000
Korea	4,026,000	2,903,000
Formosa	1,641,000	1,591,000
U. S. A.	868,000	810,000
Italy	335,000	615,000
Egypt	489,000	541,000

India is also the greatest exporter of rice in the world, although her average export rarely exceeds 6 to 8 per cent of her total production. India's export of rice in 1932-1933 was 1,887,132 tons, and its total value was Rs. 14,45,84,529.

Wheat, another very important crop in this country, occupies an acreage of about 10 per cent. of the total area sown. Its cultivation is mainly confined to the Punjab, the United Provinces, the Central Provinces and Berar, the Central India States, Bombay and Bihar. But the Punjab and the United Provinces according to the 1933-1934 figures account for about 48 per cent of the total area sown and 56 per cent of the total yield.

Wheat is the staple food of many of the people living in Northern India. India is one of the important wheat producing countries as it produces about ten per cent of the world's wheat and also occupies the fourth place amongst the wheat-producing countries of the world. Its present production of wheat however, is approximately equal to her requirements and consequently the export of wheat during the last few years was on a limited scale.

Table XXIV

Showing the position of the important wheat-producing countries of the world.

Country.	Area in acres in 1931-1932.	Production in tons in 1932.
United States (U. S. A.)	57,114,000	19,976,000
Russia (U. S. S. R.)	85,249,500	19,929,977
Canada	27,182,000	11,868,000
India	33,803,000	9,455,000
France	18,423,000	8,915,000
Italy	12,180,000	7,402,000
Argentine Republic	17,785,000	6,439,000
Australia	15,766,000	5,730,000
Spain	11,244,000	4,923,000
Germany	5,632,000	4,914,000

Sugar cane.—The area under sugar cane in India is larger than in any other country in the world, and during the last few years the acreage under this crop has been increasing very rapidly. Its cultivation at present is mainly confined to the United Provinces, Punjab, Bihar, and Orissa, but it is grown to some extent in Madras, Bombay, and Assam. The United Provinces alone has more than 50 per cent. of the total area devoted to sugar cane in this country, while it, with the Punjab, occupies about two-thirds of the total area sown to this crop.

In spite of the large acreage devoted to this crop, India does not produce enough sugar to meet her own demands. This is largely due to the low yields per acre, which makes it unable to meet the demands of the population of this country. It has therefore been necessary to import foreign sugar into India. The amount of import of sugar to India in 1931-32 was approximately 516,000 tons, valued at Rs. 60,100,000. India's annual consumption of sugar calculated for the quinquennium ending 1930-31 was 961,000 tons. And, in spite of the very rapid progress made during the last few years in the

manufacture of sugar, the sugar factories in India were estimated to have produced only 810,000 tons of sugar in 1935-1936.

TABLE XXV.

Showing the position of India in the world's production of raw sugar.

Country.	Area in acres	Total yield in tons in 1932.
Java and Madura	438,000	11,325,000
Hawaii	140,000	7,633,000
Porto Rico	256,000	5,816,000
India	2,971,000	4,676,000
Formosa	244,000	4,641,000
Argentine	366,000	3,711,000
Australia	242,000	3,703,000
Peru	89,000	3,258,000
Union of South Africa	110,000	2,812,000
Mexico	186,000	2,728,000

Cotton.—India is one of the most important cotton-growing countries of the world. Its acreage, as well as its total production, is second only to that of the United States of America. The area devoted to this crop in India has varied during the last five years ending 1934-1935, from about 22 to 25 million acres, and its total production has also varied from a little over 4½ to about 7 million bales annually. Its cultivation is mainly confined to the "black cotton" soil area of India but is also grown in the alluvial soils of the Indo-Gangetic plains. India is also one of the important cotton-exporting countries of the world being second only to the U. S. A. Its export in 1931-32 was 2,654,250 bales, which was about 44·5 per cent. of the total produce. America in the same year exported 11,419,000 bales.

The following table shows the position of India amongst the major cotton growing countries of the world.

TABLE XXVI.

Showing the acreage and production of the important cotton growing countries.

Country.	Area in acres in 1931-1932	Yield in 1932 (bales of 400lb.)
U. S. A. ..	38,705,000	16,252,000
India ..	23,722,000	5,979,000
Russia ..	5,367,000	1,813,000
Egypt ..	1,746,000	1,225,000
Brazil ..	1,710,000	823,000
Uganda ..	865,000	294,000
Argentine ..	336,000	179,000
Anglo-Egyptian Sudan ..	336,000	140,000
Australia ..	30,000	15,000

The above discussion clearly shows the very important place India occupies amongst the major countries as a producer of the important crops of the world. It also shows that field crop production holds a very important place in the agriculture of India. A closer examination of the above data will also show the importance of more intensive methods of cultivation as the yields per acre in India of most of the important crops are very much lower than those obtained in the other countries of the world. Thus, one can see from the figures given that while the yield of cotton in Egypt is about 300 pounds per acre, in India it is only about 100 pounds.

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CHAPTER XII.

WHEAT

Origin and history :—The growing of wheat began very early in pre-historic times. Its culture is so old that the origin of wheat is still a matter of speculation. Wheat has also been known for a very long time to people of various parts of the world. Records in ancient China show that it was cultivated there by 2700 B. C. It was also known to the ancient Egyptians and to inhabitants of Switzerland as early as the Stone Age. De Candolle believed that wheat originated in the valley of the Tigris and Euphrates, and spread from there to China, Egypt and other parts of the world. Some of the American writers believed that wheat probably originated in Syria and Palestine, mainly on the evidence of Aaronsohn who brought a type of wild wheat from that country. More recently, Vavilov, after more extensive studies of the origin of cultivated plants, came to the conclusion that the origin of the durum wheats was probably in the region of Abyssinia, whereas the whole group of soft wheats, which include the bread wheats, probably originated in the region adjoining northern India, south western Afghanistan, and the southern parts of mountainous Bokhara. This conclusion is based on the fact that there are a great number of forms of wheats showing dominant characters in these two regions.

Distribution in India.—Wheat is one of the most important crops in India. The total area in 1933-40, under this crop was 35,992,000 acres. The total estimated yield during that year was 9,424,000 tons. Its distribution according to provinces is as shown in Table XXVII.

(*a*) The wheat plant ; (*b*) an ear of Pusa 4 wheat ; and (*c*) an ear of a local (Allahabad) wheat. *(Draw by N. N. Uzir).*

TABLE XXVII

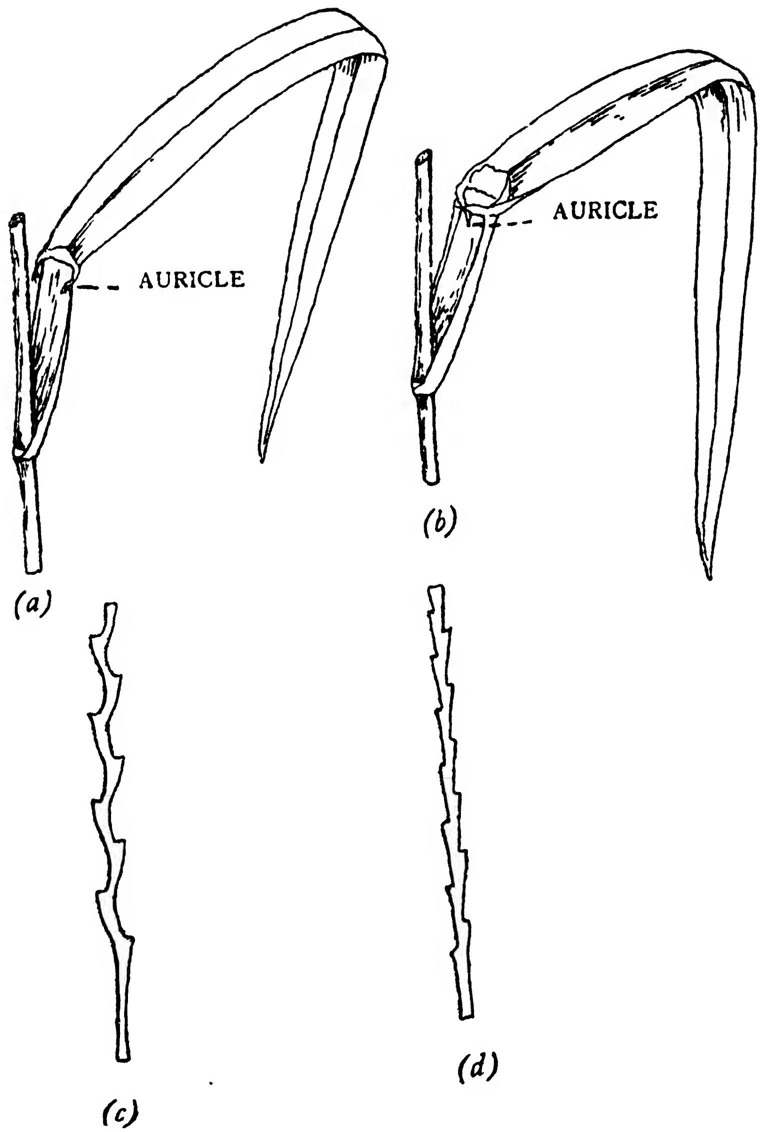
Showing the distribution of wheat according to provinces.

Province	Area in		Yield in tons.	
	1933-34	1937-38	1933-34	1937-38
Punjab	9,778,000	9,945,000	2,794 000	3,724,000
United Provinces	8,453,000	7,800,000	2,537,000	2,777,000
C. P. and Berar	3,441,000	3,358,000	715,000	673,000
Bihar and Orissa	1,222,000	1,098,000	476,000	307,000
		4,000		1,000
Sind	1,221,000	1,155,000	357,000	
Bombay	1,926,000	1,827,000	328,000	386,000
N. W. F. Province .. .	1,041,000	1,028,000	249,000	268,000
Bengal	145,000	161,000	41,000	45,000
Delhi	46,000	56,000	18,000	20,000
Ajmer-Merwara	29,000	21,000	7,000	7,000
Total for Indian States . ..	8,695,000	9,165,000	1,902,000	2,153,000

Thus this crop is grown practically all over India except in the regions at the mouth of the Ganges in Bengal and many of the districts of Assam. However, the greatest part of this crop is grown in the northern provinces of India and much of it on the Malwa plateau. On the average the Punjab and the United Provinces together have about 50 per cent. of the total area under wheat in India, and produces about 61 per cent. of the total crop.

Botanical description.—Wheat is a member of the grass family, one of the most important of the families of plants to man, as almost all of the cereals, sugar cane, and many of the important forage crops belong to this family. Thus rice, barley, *jowar*, *bajra* and sugar cane are all related to wheat. Wheat is an annual plant, that is, it grows and dies in the course of one year. In this country, wheat is grown only in the winter reason.

The wheat plant usually grows to a height of about 2½ to 5 feet, depending on the fertility of the soil and on the variety grown. In



(a) Part of the wheat stem showing the auricles; (b) part of the barley stem also showing the auricles; (c) part of the wheat rachis; and (d) part of the barley rachis.

general, the macaroni wheats are also taller than the common bread wheats. But the particular height attained depends also on external factors. The stems or culms of the wheat plant are round or cylindrical. In most varieties of the bread wheats the stems are hollow except at the nodes where they are solid, but in a few varieties of macaroni wheats the internodes are completely filled with a soft pith. During the early growth of the stem, the nodes or joints are very close together but later the internodes elongate until the plant reaches its full height.

Wheat in common with other cereals throws out branches, which are known as "stools" or "tillers" The degree of tillering depends on the race or variety grown, as well as on other external influences, such as the fertility of the soil, spacing, and seasonal conditions. These tillers develop from buds that are produced in the axil of the leaf, at the underground nodes. Some wheats have been known, under favourable circumstances, to produce fifty or more tillers in one plant.

The young shoots of wheat sometimes show distinct differences in habit of growth. Some types at the early stages of growth stand up more or less erect and are therefore known as the "erect" types. The second group of wheat show a prostrate habit of growth, and hence are known as "creeping" wheats. This creeping habit is believed to be very closely related to winter hardiness. The wheats with this habit also do not easily lodge. The third group of wheats show a habit intermediate between the erect and the prostrate types, and may be called an "intermediate" type.

Another characteristic of wheat stems in common with other cereals is what is known as "lodging", which is the bending of the plants causing them to lie more or less flat on the ground. This phenomenon is usually associated with weak stems and also with nutrition, especially with the presence of an excess of nitrogen in the soil, or with an excess of irrigation water. But the character of the root system also influences the degree of lodging in the wheat crop. Lodging may also be encouraged by the crowding of the plants, which causes weakness of the stems due probably to an etiolation effect caused by insufficient light. From the chemical view point, investigations by Lawes and Gilbert have shown that lodging is associated with liquification of the tissues and a correspondingly low proportion of silica.

Stems of wheat do not elongate indefinitely but sooner or later produce ears or spikes which bear the grain. This phenomenon is known as the "shooting' of the ear or "booting". The time taken to reach the "earing" stage, in other words, the "earliness" or "lateness" of the wheat crop, is a character inherent in the plant itself, and is therefore, more or less a constant hereditary character.

The wheat *leaf* consists of four parts (1) the blade or lamina; (2) the sheath, the part which clasps the stem tightly; (3) the ligule or rain-guard, a thin membrance growing at the junction of the blade and the sheath; (4) the auricles, which are curved claw-like appendages attached to the base of the blade and generally clasping the stem, from opposite sides.

The blade of the wheat leaf varies considerably in different varieties in length, width, smoothness, and prominence of veins. The sheaths normally cover about the lower two thirds of the culm, and overlap on the side opposite the blade. The leaf sheath may vary in colour from purple to light-straw. The ligule or rain-guard prevents the entrance of rain water, dust, aphides and other insects, between the sheath and the stem. This structure is sometimes made use of in distinguishing wheats from barley or oats. Oats do not possess any auricles, whereas those in barley are very prominent and much larger and more conspicuous than those of wheat. These structures are either light-green or pinkish in colour.

The **inflorescence** of wheat is arranged in a long, narrow, compact cluster at the top of the stem and is known as the "spike" or "head". It is made up of groups of flowers known as spikelets, each spikelet being a flower or a group of flowers enclosed in a pair of glumes, which are concave scales or bracts inserted on a short stem known as the rachilla. In wheat, there is only one spikelet at a node on the rachis, whereas in barley there are three spikelets at each node. That portion of the stem extending through the spike, to which the flowers are attached is known as the rachis. The spikelets are borne on alternate sides of the rachis, which gives it a zig zag appearance. The character of the rachis may be used to distinguish wheat from barley, as in the latter the rachis is more flattened and less zig zag. At each node on the rachis in the wheat plant there is a cushion-like end

for the attachment of the rachilla. This character also is some times used for distinguishing wheat from barley.

Spikes differ greatly in form and degree of compactness. In some wheats the spikelets are specially crowded on the ears near the tip, but arranged in a lax, open manner toward the base. Such ears are referred to as "clubbed", and hence the name of "club wheat" is given to these varieties.

Spikes may be either "awned" or "awnless". An awn is a tapering projection from the flowering glumes (lemmas) at each spikelet. Awns are agriculturally important for they are characters which are readily apparent, and hence used in classifying wheat. Awns usually decrease in length from the basal part of the spike upward. The length of the awns however depends on the variety or race of wheat. The macaroni or *durum* wheats usually possess very long awns, whereas the bread wheats are either awned or awnless, and when awned the length of the awns is usually less than that of macaroni wheat. Absolutely awnless wheats are however of exceptional rarity. Hence in the classification the term awnless or beardless is used for those wheats in which the awns are altogether absent or not more than one centimeter in length and confined to the tip of the ear. Truly bearded wheats usually have a uniform distribution of awns from the top to the bottom of the spike and the longest is never at the top. On the basis of this character, all varieties of wheat are classed as awned (bearded) or awnless (beardless). Awns also possess different colours, which vary from light-straw colour, to red and black. The black pigment however may appear or disappear according to certain climatic conditions, such as intensity of light, heat and moisture during the ripening period. This character, therefore, cannot be relied upon for use in the classification of wheats.

Spikes may also be flattened parallel to or at right angles to the plane of the face of spikelets. All common bread wheats are flattened parallel to this plane and are therefore dorsoventrally compressed. But the spikes of macaroni and club wheats are flattened at right angles to the plane of the face of the spikelets and are therefore laterally compressed.

A wheat flower consists of three stamens with thread-like filaments and rather large anthers. The single ovary has two feathery stigmas.

There are two lodicules, structures which are instrumental in the opening of the flowers. This is performed by the swelling of the lodicules causing the separation of the lemma and the palea or palet. The spike takes several days to complete its flowering. Considering the entire plant, flowering takes place on the main stem followed by the tillers in the order of their development.

Wheats are generally considered to be self-fertilized plants, although a very small percentage of natural crossing may occur. Natural crossing however is believed to be more common in macaroni or durum wheats, and in hot dry countries more than in countries with a wet and cold climate. In this connection, Howard reports that more cross-pollination took place at Lyallpur in the Punjab than at Pusa in Bihar.

The **roots** of a wheat plant like those of other grasses are fibrous. On the germination of the grain, seminal or temporary roots are produced, and are then followed by permanent roots usually at some distance above the temporary roots. The first permanent roots are usually formed at a depth of about one or two inches below the soil surface, regardless of the depth at which the seed is planted. These permanent roots at first spread out laterally and then descend almost vertically downwards sometimes reaching a depth of about four feet under favourable conditions. The number of roots generally increases with the number of tillers in the plant.

Ecological factors.—Wheat is adapted to varying conditions of climate and soil. In India, however, wheat growing is mainly confined to the regions of cool winters. Its cultivation is therefore confined to the northern, and to some extent to the central portions of the country. In general it does not do well in the southern part of the country nor in the humid regions, such as Bengal. The best wheats are produced in the northern most part of the country where the winters are cold.

Although most of the wheat areas in this country are in the low level plains of the Indus and the Ganges, some wheat however, is also grown in the higher regions, such as on the Malwa plateau, the hilly regions of the North-West Frontier Province, and to some extent in the regions of the Himalayas,

Wheat is grown in India where the annual rainfall varies from 5 to 45 inches. But in most places where the rainfall is less than 30 inches, irrigation is required for profitable production. But even in such regions "dry farming" or "*barani*" cultivation is sometimes adopted. The yield from this method of cultivation is usually very low.

It must not be inferred, however, that one type of wheat is grown in all those regions where there are varying amounts of rainfall and different degrees of temperature. Usually durum or macaroni wheats require less rain than the common bread wheats.

Wheat is also grown in different types of soils in this country, but it does best on the heavier soils such as loams and clay loams. And while it makes its best growth in the alluvial soils of the Indo Gangetic plain, it also does well on the black cotton soil of Central India and parts of the Central Provinces. But the bread wheats are typical of the alluvial soils, whereas the durums are mainly confined to the black cotton soil.

Wheat in India is frequently subject to frost, but it is seldom severe enough to do much damage. However in case of late frost, after the ears have headed out, the damage caused to the crop may be serious.

Classification of the Indian Wheats.—According to A. E. Watkins, there are fourteen different species of wheat in the genus *Triticum,* divided into three groups on the basis of the number of chromosomes. The first group, represented by *T. ægilopoides* Bal., a wild form of wheat, contains 14 chromosomes. The second group which is represented in India by *T. durum* Desf. the macaroni wheat, and *T. dicoccum* Schubl., emmer wheat, contains 28 chromosomes. The third group, which is represented in India by *T. vulgare* Host., the common bread wheat, and *T. sphærococcum* Perc., the Indian dwarf wheat, contains 42 chromosomes.

A Key to the Classification of Indian Wheats.

A. Stems solid, or hollow with thick walls ; rachis more or less fragile ; empty glumes long and narrow with outer face flattish ; keel very prominent from tip to base ; grains long and narrow ; number of chromosomes, 28.

B. Apical tooth on empty glumes short and blunt ; coleoptile 4-6 nerved.

T. dicoccum (emmer).

BB. Apical tooth on empty glumes stout, generally acute, and curved inwards ; coleoptile 2—nerved. *T. durum* (macaroni wheat.)

AA. Stems hollow with thin walls, (occasionally in *T. vulgare* with solid upper internodes) ; rachis, tenacious ; empty glumes, broad with outer face, convex ; keel, less prominent or in the upper half only ; grains, plump ; number of chromosomes, 42.

B. Apical tooth on empty glumes, short, more or less acute, or sometimes prolonged into an awn ; grains, rounded on dorsal side.
T. vulgare (common bread wheat).

BB. Apical tooth on empty glumes, strong, curved and scabrid ; grain angular. *T. sphærococcum* (Indian dwarf wheat).

Emmer (*T. dicoccum*, Schubl).—Howard reports that there is a single variety of emmer in this country. It occurs in the south of the wheat-growing area—in Bombay, Madras, Mysore and to a very small extent in Berar. It is believed to have developed from *T. diccoides* Korn, a wild form. Emmer is one of the most ancient cultivated cereals. It is grown to some extent in Spain, Italy, Germany, and Russia.

Macaroni wheat (*T. durum* Defs.).—This wheat is grown largely in the black cotton soils in Central India, parts of the Central Provinces and to some extent in the western districts of the Punjab, Madras, Mysore and in the Malda district of Bengal. The Malwi wheats of Central India and the *dautia* wheats of Hoshangabad in the Central Provinces are durum wheats. The *wadanak* wheats of the Punjab are also forms of durum and are reported to be good for making *chapaties*, and are used exclusively in the manufacture of sweetmeats which are eaten by all classes of people. In European countries, this wheat produces the flour from which macaroni is made, whence it got its name. It is commonly grown in Italy, Central and South America, Russia, and the United States of America. Durum wheats are believed to have descended from emmer.

Common bread wheat (*T. vulgare*, Host) —The common bread wheat is typical of the alluvial soils of the Indo-Gangetic plains, especially in the Punjab, the United Provinces, Bihar, Sind and parts of Rajputana. The bulk of the Indian crop, therefore, consist of this type.

Indian dwarf wheat (*T. sphaerococcum* mihi).—Wheats of this type were thought by Howard to belong to *T. compactum* or the Club wheats of western countries. Percival, however, is of the opinion

that these are not club wheats but belong to the species *T. sphaerococcum* which he designated by the common name of Indian dwarf wheats. These are said to occur in the western districts of the Punjab and to a small extent in the Central Provinces and in the United Provinces. These types are characterised by very short and compact heads; the grain also is much shorter than that of common bread wheat.

The **wheat area** in India may be roughly divided into two portions: (1) the alluvial soils of the Indo-Gangetic plain, where the bread wheats are commonly grown, and (2) the black cotton soils of Central India, the Central Provinces and Bombay where the macaroni wheats are mostly grown. The types of wheat more recently recommended by the agricultural departments, for the different wheat areas, are the following:—

1. In the Punjab area.

   (*a*) *Punjab 8A.*—This has been a standard wheat of the Punjab, for almost a quarter of a century. In the early stages, the growth of this wheat is decumbent, that is, not erect as 9D. The grain is amber-coloured and very plump. It is a bearded wheat with grains which are moderately hard. It is also a good tiller and when ripe does not shatter the grain easily.

   (*b*) *Punjab 9D.*—This is a fully bearded wheat with white awns and white pubescent glumes. Its growth in the early stages is erect. It is an early wheat, ripening about a week earlier than 8A. It, however, possesses weak stems and is therefore likely to lodge in conditions where there is plenty of moisture, and also where the fields are rich in nitrogen. It does not tiller as well as 8A, which necessitates a higher seed rate.

During the last few years the Punjab Agricultural Department has put out two very promising crosses known as Cross 518 and Cross 591. These are also bearded wheats and have been found to do quite well, and in certain cases were better than the two standard wheats of the Punjab mentioned above. It has, however, to be seen yet how far these wheats can replace the other two wheats of the Punjab.

2. In the United Provinces.

(*a*) *Cawnpore* 13.—This is a standard wheat of the province, and has been distributed by the Agricultural Department since 1926. It is a bearded wheat, and a fairly heavy yielder.

(*b*) *Pusa* 52 —This is the product of a cross between Pusa 6 and Punjab 9. It is a bearded wheat, fairly high yielding and fairly resistant to rust. This type possesses white glumes which are glabrous, and also white awns. The spike is somewhat lose at the base but more compact towards the apex.

(*c*) *Pusa* 4.—This wheat was produced by selection from indigenous forms. It is a beardless wheat, stands well, and is fairly rust resistant. Its glumes are white and pubescent, a character which distinguishes it from Pusa 12 which is similar to it, but which possesses reddish glumes which are glabrous.

(*d*) *Pusa* 12.—This wheat is beginning to lose its popularity in this province.

During the last few years other wheats have been tried with some success in certain parts of the province. They are Pusa 111, Pusa 165, Punjab 8A, and Cross 518. They are, however, under further trial before they can be generally recommended to cultivators in different parts of the province.

3. In the Central Province, A 115, more commonly known by its trade name of *sharbati* is the most popular wheat in the province where *pissi*, a bread wheat is being grown. This is a wheat with a relatively strong straw and fairly hard grains. It is also claimed to be less susceptible to rust than most of the other wheats of the province In 1933 however, this wheat also suffered very badly from an attack of rust.

4. In Bihar, Pusa 52 for several years has been the most popular wheat. In recent years, however, Pusa 165 an awnless variety, and Pusa 113 have been found to even do better than Pusa 52 in certain parts of the province.

5. In Central India and Rajputana both species of wheat, the durums and the bread wheats, are grown. Rajputana is more suitable for the wheats grown in the Punjab. Thus Punjab 8A, Cross 518, and Cross 591 have been found to do fairly well in certain parts of Rajputana. On the other hand, in the Malwa plateau of Central India, the local types of wheats have, in general, proved superior to the imported varieties. The bread wheats grown in the Malwa plateau are represented by the *pissi* types and the durums by the Malwi types.

6. In Sind, four types of wheat are now being distributed by the Agricultural Department. Two of these are local selections, and the other two are imported varieties. They are C. Ph. 47, A. T. 38, Punjab 8A and Pusa 114.

7. In Bombay Presidency a new strain of wheat known as Bansipalli 808, a macaroni wheat, has been released by the Department of Agriculture for the Nasik district. It was obtained from a Cross between the improved Bansi strain 168, and Kala-Khapli 568, and ripens about two weeks earlier than the local wheat and is claimed to be superior in yield and quality.

CULTURAL METHODS

Preparation of seed-bed.—An ideal seed-bed is one in which the soil has been thoroughly pulverized and then compacted. That is the lumps are crushed, but not to the extent of forming a dust mulch, as this generally forms a hard crust on the surface if rain occurs. This crust may prevent the seedlings from penetrating the soil.

The method of preparing a seed-bed in this country varies in general with the soil conditions, and also depends on whether the crop is irrigated or non-irrigated. In the alluvial soils that is, in the Punjab, the United Provinces and Sind, the usual method of preparing a seed-bed is by repeated ploughing and cross-ploughing until the soil is thoroughly pulverized. In some cases a farmer ploughs as many as fifteen times. But the more common practice is to plough from eight to ten times. These repeated ploughings are usually done during the monsoon with only one or two ploughings following the monsoon during the months of September and October. After the monsoon is

over, the ploughing is usually followed by operating a beam or planker which is known as the *sohaga* in the Punjab and *patela* in the United Provinces. When the crop is grown under irrigation, the number of ploughings is much less, usually two or three. This is however, always followed by a planker in order to crush the lumps.

In the black cotton soil area, that is, in Central India, Bundelkhand, the Central Provinces, and Bombay, the practice is quite different from that in the Indo-Gangetic plain. Instead of a plough, a *bakhar* is used in the preparation of the seed-bed. This is an implement typical of this area and consists of a blade about twenty inches long and four inches wide, fixed at both ends to a beam of wood. It penetrates the soil to a depth of about 8 inches and pulverizes it. This makes the operation of planking or beaming unnecessary. The *bakhar* is usually operated during April or May and once or twice during the monsoon and again in September. The land is cultivated again with a *bakhar* in October previous to sowing.

Date of Sowing.—Sowing usually begins about the middle of October and continues to the middle of November. This period of sowing is general throughout the country except in the North-West Frontier Province and adjoining parts of the Punjab, where the date of sowing is a little later than in the other wheat areas of the country.

Method of Sowing.—Wheat is sown in three ways: (1) broadcasting, (2) dibbling, and (3) drilling. Broadcasting consists of scattering the seeds by hand, usually followed by harrowing or ploughing in order to cover the seed. This method is very inefficient and usually requires more seed per acre than the other methods The seed also is not deposited at a uniform depth. Often many seeds are left on the surface where they cannot germinate. They may therefore be picked up and eaten by birds. The seeds also are not uniformly distributed over the field. Hence this method of sowing seed is not to be encouraged. However this practice is followed to a certain extent, in all parts of India where wheat is grown. It is probably less objectionable when the surface of the soil is moist. The amount of seed required per acre by this method varies from 40 to 50 *seers*.

"Dibbling" consits of dropping the seeds by hand into the furrows that have been opened by a plough, the sowers usually following the

plough. Dibbling is generally done by the women and children of the family, while the man ploughs. This method is less objectionable than broadcasting, but is probably more laborious and covers a smaller area per day. After dibbling, planking becomes necessary in order to cover the seed, although this is sometimes done by the feet of the sowers which slows down the sowing operation The quantity of seed required per acre by this method may vary from 30 to 40 *seers*. This method is sometimes used in the canal colonies of the Punjab and certain parts of Bombay on irrigated land.

The method of drilling wheat varies in different parts of the country. In the United Provinces and the Punjab, drilling consists of dropping seeds into a bamboo tube fastened to the plough in such a way that the seed drops just behind the point of the plough, in the bottom of the V-shaped furrow. The seed is partly covered by soil falling back behind the plough. Usually two persons are required for sowing by this method, one person driving the bullocks and operating the plough, while the other drops the seed into the funnel-shaped mouth of the tube. The seed is usually dropped by a woman. The depth of sowing can be varied by adjusting the bamboo tube. At the ends of the furrows blanks are apt to occur due to the turning of the bullocks. This is therefore corrected by sowing a few rows across the field to fill up these blanks. The quantity of seed required by this method varies from about 25 to 30 *seers* per acre.

In the Central Provinces and Berar the seed is sown by means of a three-coulter drill known locally as the *tifan*. In this implement three hollow tubes are attached, one to each drill, which meet at the top in a large wooden funnel. The seeds are dropped into this funnel by hand and are distributed in the three tubes. Thus this drill can sow three furrows at a time. The quantity of seed sown per acre by this drill is about 30 seers.

In the Bombay Presidency a heavy two coulter drill is used, which is similar to that used in the Central Provinces. The seed rate by this drill is about 25 to 30 seers per acre.

Another type of machine which is being used more and more in this country for the sowing of wheat is a drill introduced from western countries. This drill varies in size, depending upon the power used for drawing it. As bullocks are used in this country for draught

purposes, smaller types are used. Such types can generally sow about five or six rows at a time. Therefore the area covered by these drills is much greater than that covered by local types. The machine is efficient as it distributes the seed uniformly at a proper depth. It works well only in case the seed-bed is in excellent condition.

As a comparison of these different methods of sowing, it may be said in general that drilling is more efficient than either "dibbling" or broadcasting, and it produces an increased yield. This increased yield is due to the fact that seed is sown at a uniform depth, making germination more or less uniform. Drilling also requires less seed per acre for sowing. Wheat seeds should be sown at the proper depth, as the permanent roots are always produced at about the same distance below the soil surface, regardless of the depth at which the seed is sown. When the grain germinates three or more roots are produced. In the early stages in the development of the plant, the permanent root system is produced above the primary roots from the "crown" and these always develope within an inch or two of the soil surface. Hence if the seed is planted too deep the distance between the seed and the crown becomes unnecessarily long, and much of the energy derived from the seed is then wasted in the process.

Cultivation after sowing.—After the seed has been sown very little is done in the way of hoeing and cultivating, especially when the wheat is sown under dry-farming conditions. If it is grown as an irrigated crop, the land is divided into small compartments or *kiaris* for purposes of irrigation. In the Punjab, this is done, before the germination of the seed, by means of a *jandra,* a large wooden rake. The number of irrigations given to the crop varies according to the soil conditions and climatic factors of the locality. In the Punjab the number of irrigations after sowing is generally two or three. In the United Provinces also it may vary from one to three. In certain parts of Rajputana the number of irrigations may be as many as six.

The wheat crop is usually not weeded except by the best cultivators. The most troublesome weeds in the wheat fields in the Punjab as well as in the United Provinces, are *bathua* (*Chenopodium album*) and *piazi* (*Asphodelus fistulosus*) The wheat crop is sometimes subject to "lodging" or "laying" of the crop. This phenomenon is

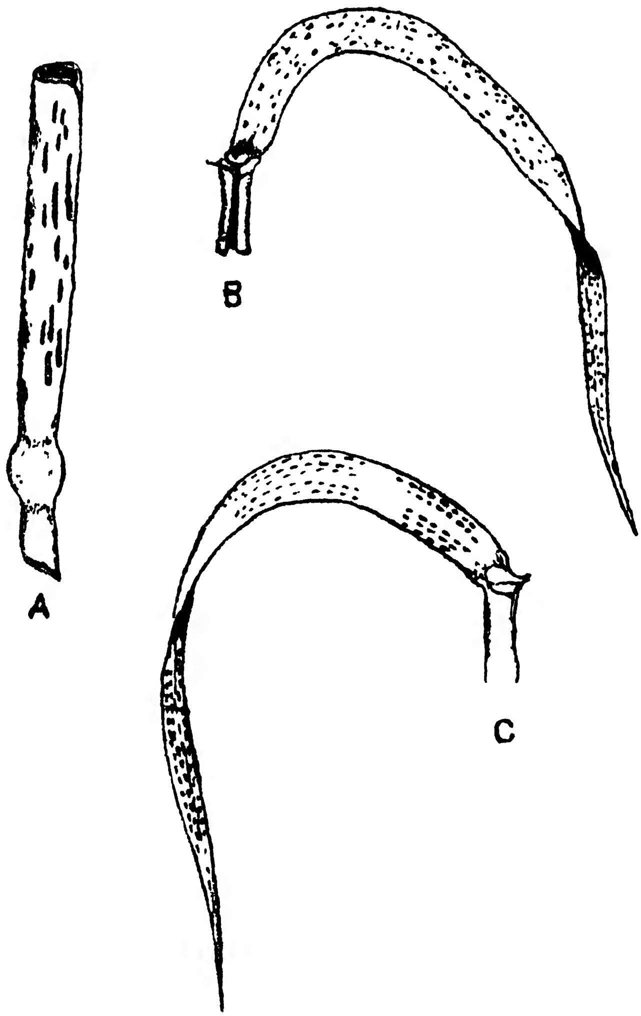
caused by the weakness of the straw, or of the root-system, and is generally brought about by an excess of moisture in the soil, or its high fertility. If the crop bends down at the early stages of its growth, the plants may again stand upright due to the geotropic stimulus to the plant. But if it takes place late in the growing season, the crop will usually remain flat on the ground. Wheat will usually lodge when subjected to heavy rain accompanied by high winds and hail.

Harvesting and threshing.—The harvesting of wheat begins in March in the Central Provinces and parts of Central India. In the United Provinces wheat is usually harvested in the latter part of March and up to the middle of April. In the Punjab the harvest usually begins about the middle of April and extends into May. In the North-West Frontier Province the harvesting season is much later, starting about the beginning of June and is not generally over till the end of that month.

Wheat is generally harvested by cutting with a sickle, a small hand implement known as the *hansia* in the United Provinces or *daranti* in the Punjab and Central India. After the crop has been cut it is tied into bundles and carried to a central place and stacked. The crop is usually fully mature and therefore can be threshed immediately.

Threshing is generally done in most parts of the country by treading with bullocks. The wheat is spread on a threshing floor, which is generally made of earth. The bullocks are driven round and round until the grain is separated from the chaff. The final separation of the grain from the *bhusa* or broken chaff is done by winnowing from a basket which is known as a *sup* or *chhajj*. The basket is held high over the head and is shaken, allowing the *bhusa* and grain to drop from the basket slowly to the ground. The steady winds which generally prevail at this time of the year separate the *bhusa* and dust from the grain. The *bhusa* being lighter, is carried further away than the grain.

After threshing the grain is stored either loose or in bags in rooms. Sometimes it is stored in mud bins. These are of several types, varying in different parts of the country. The grain which is kept for home consumption or seed purposes is generally stored in mud bins known as *khuttis* when dug in the ground or *kothis* when above



Rust diseases on wheat. A, *P. graminis* or black stem rust; B, *P. glamarum* or yellow rust; and C, *P. triticina* or Orange rust.

ground. Sometimes earthen jars (*bharolas*) are also used for storing wheat which is to be used in the home.

Grain intended for sale is generally disposed of to buyers soon after threshing.

DISEASES AND PESTS.

Rusts.—Rusts are the most serious diseases of wheat in India. The occurrence of these rusts on the wheat crop greatly reduces the yield. Even if the loss due to rusts is put at a very conservative estimate of about five per cent., the loss to the country on the whole would amount to several million rupees annually.

Three kinds of rusts generally occur on the wheat crop in India. These are known as orange rust, caused by *Puccinia triticinia* Erikss., yellow rust, caused by *P. glumarum* Erikss., and black rust, caused by *P. graminis* Pers.

Orange or brown rust is the earliest to appear on the wheat crop. In Bihar it sometimes appears as early as November, but more often the attack begins at the beginning of the year. This rust attacks the leaves almost exclusively, but may appear also on the sheath and very rarely on the stems. It may be distinguished from the yellow rust by the fact that its pustules are not arranged in regular order but scattered on the leaf in an irregular fashion. The pustules are bright orange when fresh but when old are similar to yellow rust. They occur usually on the upper surface of the leaf.

Yellow rust usually appears later than the orange rust but earlier than the black rust. It attacks the leaves most severely but also, in severe cases, leaf sheaths, culms and even ears. The rust appears in long rows of pustules which are small and oval, and are lemon yellow in colour. The pustules remain covered in the epidermis for some time; but on bursting, a yellow powder is shed.

Black rust attacks the stems most severely, then the sheath, the leaves and the ears. It has sometimes been called for that reason the black stem rust. This is the last to appear, usually about the month of March in northern India. The pustules are large, elongated, running together and bursting early. In bursting it breaks up the epidermis into large fragments, and exposes a brown powder which, as the season advances, changes to black. It is found in all parts of the plant, but least on the leaf blade.

These three types of rust occur in the United Provinces and Bihar every year. All these may sometimes occur on the same plant. In Bombay and in the Central Provinces orange rust does not usually occur except in years of very severe rust attack. In the Punjab also this rust is not as common as the other two. Black rust is not considered as destructive in India as in some other countries such as Australia and the United States. In India yellow rust is probably responsible for the major damage done to the wheat crop.

The occurrence of rust epidemics depends on several factors, such as rain, high humidity, over irrigation, and a thick stand which produces a high humidity of the air within the crop itself. The manner in which rusts appear annually in the plains of India has not been satisfactorily explained. Several views have been advanced to explain this annual outbreak of rust. These may be briefly enumerated as follows :

1. According to one view, which is commonly accepted in America it is believed that the barberry bushes (*Berberis lycium* and *B. aristata*, etc.) which grow wild on the Himalayas, are the host plants which harbour this parasite during the hot summer and that spores from these plants spread to the plains during early winter and infect the crop.

2. The parasite is harboured during the summer by stray volunteer plants of wheat, which may naturally grow during the rainy season following the hot weather.

3. The parasite lives on some other grass during the summer months.

4. The parasite lives in the soil until the new crop is ready for infection

5. The parasite lives in the protoplasm of the grain cells, and when conditions become favourable it appears on the external parts of the plant.

Extensive researches carried on under the Imperial Council of Agricultural Research seem to indicate that rust outbreaks in this country are brought about by the dissemination of spores from centres of infection which are located at higher altitudes, such as the Siwalik Range in the United Provinces, the Murree hills in the Punjab, the

Western Ghats in the Bombay Deccan, and the Nilgiris and the Palni hills in Southern India.

This disease cannot be controlled by direct treatments. The best method for combating it is the growing of varieties of wheat which are resistant to rust. A few such types have been produced, which are calimed to be resistant to certain physiologic forms of rust. Of the Pusa varieties, Pusa 114, P. 120, P. 125 and P. 165 have been claimed to be highly resistant to one form of orange or brown rust.

Loose smut (*Ustilago tritici*).—This disease is quite common in the wheat-growing provinces of India, especially in the Punjab. It very seldom becomes epidemic and therefore, ordinarily, does not do much damage The ears of the infected plants are black, the black powdery material being found in place of the grains. These masses of black powder are covered with a thin membrane which sooner or later bursts exposing a dark powdery mass of spores which are blown off by the wind, leaving a bare rachis behind.

Infection takes place during flowering; the spores falling on the flower germinate and enter the developing grain. The fungus lives inside the grain until the seed is sown. After the seed germinates the fungus developes along with the plant and produces its spores in the place of the wheat grains.

Several methods of controlling this disease have been devised, but the simplest and one which can be easily adopted in Northern India is known as the "solar energy method". In this method the seed is soaked in water for about 4 hours in the morning, say from 8 a.m. to 12 noon, on any bright summer day. The seed is then taken out and spread in the sun for four hours, that is from 12 noon to 4 p m. When the seed is thoroughly dried it is stored until sowing time. By this treatment the fungus inside the grain is killed by the light and heat from the sun, whereas the grain remains unharmed.

Bunt or stinking smut (*Tilletia sp*). - This disease does not appear to be common in the plains of India but occurs in parts of Baluchistan and the Western Himalayas, extending into the Punjab, and is very common in Kashmir. The disease in India is caused by three species: *Tiletia caries*, *T. foetens* and *T. indica*. The first two are confined to the cooler regions whereas *T. indica* is more or less confined to the plains. Plants affected by this disease possess ears

which are of darker green colour and more open than the normal ones. The plants also mature more rapidly. The ears thus contain a black mass of spores which stink like rotten fish. The black mass is however kept intact and not blown away by the wind as in the case of loose smut. The disease spreads by the spore-balls becoming ruptured during harvesting and threshing, and the spores coming in contact with sound grains. The spores adhere to the grains and germinate when the seed is planted, entering the plant through the tender tissue of the wheat seedling. The fungus developes along with the plant and produces its spores in the place of the grains of wheat.

The disease may be controlled by several methods. The earliest method adopted was to steep the grain in dilute formalin solution. The solution is made of one pound of commercial formalin (about 37 per cent. formaldehyde) in forty gallons of water. This is sufficient to treat 80 maunds of grain. The grain should be covered with moist gunny bags for about two hours and should be sown preferably within twenty-four hours.

Another method used for treating this disease consists in the use of copper compounds, such as copper sulphate, and copper carbonate dust. Experiments have shown that copper sulphate injures the grain, thereby reducing the germination and that copper carbonate dust is more effective. When copper carbonate dust is used, the grain is thoroughly dusted with it. This is usually done by sprinkling the dust on the seed followed by repeated turning of the seed until every grain of wheat has a coating of the carbonate dust. In doing this one should be careful not to inhale the dust as it is poisonous. This may be avoided by tying a cloth over one's nose and mouth.

Minor diseases.—Certain other diseases have been reported to attack the wheat crop, but their damage is slight and they are therefore of little economic importance. Among these are (1) a leaf spot disease caused by *Helminthosporium tritici-repentis* Died. reported from Pusa in Bihar, (2 a foot-rot disease (*Helminthosporium sp.*) reported from the Central Provinces, and (3) a root-rot disease caused by *Pythium graminicolum*, reported from the Bombay Presidency.

Insect pests.—Among the numerous insect pests which attack the wheat plant, the wheat stem borer (*Nonagria uniformis*) is one which does the most damage in this country. This insect at one stage

of its life is a caterpillar and it is during this stage that it is very destructive. The fullgrown caterpillar is about one inch long, smooth, with a brown head and a rather pinkish body. The caterpillar bores into the stem of the wheat plant, feeding on the centre of the stem. In the adult stage this insect is a moth. The insect may be controlled to some extent by destroying all the withered plants which have been attacked by this pest.

Another common insect pest which attacks the wheat crop is known as the aphis. This insect attacks the leaves and ears of the wheat plant. No practical remedy has been suggested for the control of this insect, although spraying will control it to some extent. The insect is also controlled biologically in nature by certain insects known as lady-bird beetles, which flourish at the time when aphides occur.

Insects of stored grain.—Wheat stored for consumption or seed purposes is often attacked by insects These insects attack the grain at different stages of their life history and, in extreme cases, reduce the grain into flour and dust. The most common of these stored grain pests is probably what is known as the rice weevil (*Calandra oryzae L.*) This is a small dark-coloured weevil about one-eighth of an inch long with a prominent curved snout. It lays its egg on the wheat grain, one female laying about 400 eggs. The eggs are hatched after six or seven days. Each larva bores into the grain with its strong teeth and eats out a large portion of the grain, forming a cavity in which it lies. The insect completes its life cycle in about a month, and there are three or four generations in a year.

Another common insect pest of stored wheat is what is known as *khapra* (*Trogoderma khapra*). The adult is a small active brownish-black beetle. The female is bigger than the male. The adult lives only for a few days. The whole life cycle is completed in about a month in the summer, and there are usually four generations in a year. The female lays the eggs singly on wheat grains. One female lays from 35 to 60 eggs. The eggs hatch in about five to seven days. The grubs are usually small, brownish and with long hairs on their body, specially at the posterior and they feed on the grain and grow bigger. The grubs are very active in the summer and abound in the upper layer of the infected grain heap and cause the greatest damage in the top six to twelve inch layer. The adults are harmless, the grubs

doing all the damage. The grubs eat the grain and the attacked portion appears whitish In extreme cases of attack, the grain is reduced to flour and dust. The damage is usually continuous and gradual, as the insect multiplies slowly.

The most common method of controlling these stored grain pests is by fumigating with carbon bisulphide at a proper strength for a definite period. Grain exposed to the fumes of carbon bisulphide at the rate of one ounce per 15 cubic feet of space for 24 hours will be free from all insects, even the eggs of the insects being killed. The grain can be removed, and after the fumes are allowed to evaporate the grain can again be stored. The carbon bisulphide is an inflammable liquid, and therefore care should be taken to see that no fire is brought near it.

In order, however, to prevent the infestation of the grain with pests it is very desirable at the outset to see that the grain is free from all infection. That is, seeds that are already infested with insects or which carry eggs of insects should never be stored.

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CHAPTER XIII.

RICE

Introduction.—Rice is one of the most important crops of the world. Its culture began in the unknown past. Evidence tends to show that rice culture began in south-eastern Asia. It is now the staple food of most of the people of China, Japan, India, Indo-China, Java, Siam and Korea. It is also grown to some extent in Italy, Spain, Egypt and many other countries of the world. The Indian crop of rice constitutes 60 to 65 per cent of the world's production, excluding China from which no statistics are available. In India it is the most extensively grown crop, occupying every year about 80 million acres. It is, however, mainly confined to the wetter parts of the country.

Distribution in India.—The distribution of rice in India according to provinces is as follows:

TABLE XXVIII

Showing the distribution of rice according to Provinces and States.

Provinces and States.	Area in acres in 1933—34,	1937—38.	Yield in tons in 1933—34,	1937—38.
Bengal	21,672,000	22,201,000	8,680,000	9,034,000
Madras	11,704,000	10,141,000	5,314,000	4,850,000
Bihar and Orissa	13,229,000	9,513,000 5,060,000	4,294,000	3,144,000 1,623,000
United Provinces	5,980,000	7,004,000	1,736,000	2,017,000
C. P. and Berar	5,637,000	5,704,000	1,657,000	1,552,000
Assam	4,698,000	5,056,000	1,421,000	1,745,000
Bombay	2,022,000	1,867,000	902,000	860,000
Sind	1,118,000	1,231,000	461,000	519,000
Hyderabad	1,307,000	962,000	364,000	368,000
Mysore	774,000	707,000	235,000	
Others				
Total ..	70,340,000	72,277,000	25,733,000	26,737,000

Thus Bengal stands first among the rice producing provinces of India, the acreage being approximately 25 per cent of that of the whole Indian Empire. The next in order of production are Madras, Bihar and Orissa, the United Provinces, the Central Provinces and Berar.

Botanical description.—The rice plant (*Oryza sativa* L.), like wheat, is a member of the grass family. The common cultivated rice is an annual plant which thrives best under swampy conditions. The plant usually grows to a height of 2 to 6 feet, but there are certain varieties which grow much taller. The plant stools freely, that is, it produces several stems or culms in one plant. At the axil of each leaf a bud is produced which may develop into a tiller. Ordinarily this occurs only from the buds at the base of the plant where, the internodes are usually very short. All the culms, therefore, appear to arise from the same place. Usually a tiller possesses fewer leaves than the main stem. If a secondary branch arises from a primary one (that is a branch arising directly from a main stem), then the number of leaves of the secondary branch are less in number than those of the primary one.

The rice culms are usually hollow except at the nodes, but when the stems are short the internodes also may be solid. Some deep-water rices have one characteristic feature, and that is that their stems grow with the gradual rise of the flood water level.

The rice leaf is similar to that of wheat, but is usually distinguishable from it by the length of the ligule, a scale-like structure which appears as a continuation of the sheath, and at the junction of the blade and the sheath. In the rice plant this structure is very prominent and is longer than in any other cereal. It is usually more than 1 cm. in length, acute or obtuse in shape, and is usually divided into two parts, by a suture from the base to the apex.

The inflorescence is a panicle. The spikelets which make up the panicle are one-flowered and laterally compressed. The lemma and palea are similar in size, but the former is five-nerved, whereas the latter is only three-nerved. Both may or may not possess awns. The lemma and the palea together are known as the "hull," and rice enclosed in the hull is known as "paddy." The rice flower contains six functioning stamens, which distinguish it from the other common cereals.

Rice is usually self-pollinated, though natural cross-pollination occurs to a more limited extent. The pollinating habit of the rice plant varies with the variety and also with environmental factors such as wind, temperature, moisture and light conditions. Sometimes pollination in the rice flower may take place even before the opening of the flower, thus making artificial cross-pollination of rice difficult The wild rice of the Central Provinces and Berar, as a rule, does not discharge the pollen until a few minutes after the extrusion of the anthers. In these rices natural crossing occurs in about 7·9 per cent of the cases.

The presence or absence of an awn is a hereditary character, although its length may be affected by environmental conditions. The presence of awns in rice as in wheat is considered an advantage as such rices are less subject to bird attacks.

The rice grain is of various textures, colours, sizes and shapes Some varieties possess semi-transparent grains, others starchy, while in others the grain may be purplish black. The grain colour is often used to determine the quality and also the variety. Usually rice with little or no red grain is preferred to one containing red colour. Although slender rices are usually preferred by consumers, millers prefer the thicker ones as these do not break so easily in milling. The rice grain is botanically known as caryopsis.

The root system of rice is fibrous. Many of the roots are in whorls, arising from below the nodes. These roots grow through the sheaths of the dead leaves extending in all directions. The depth to which these roots extend varies from 6 to 18 inches, but they are more shallow in moist ground than in dry soils. Adventitious roots are sometimes produced from the first three nodes above the ground These usually arise due to the receding of flood water, thus enabling the plant to support itself.

Rice consists of a vast number of varieties which differ markedly in their demands upon, and response to, the environment. Its culture is mainly confined to the humid regions of the tropics. It does not grow well at low temperatures. It is able to make use of the ammonium nitrogen better than the nitrate nitrogen.

Rice has been grown in the Himalayas up to 8000 feet. Different varieties of rice however can stand different temperatures. It is

for this reason grown to some extent in several parts of India where it is not commonly grown, such as in Kashmir and the Punjab.

The rice plant generally requires a heavy type of soil, usually clay loam to clay, although it is known to do well on loam where sufficient water is available. Evidently, water is a limiting factor in the production of the major crop of rice. On this account, for rice culture, a soil underlaid with a more or less impervious stratum should be preferred.

Classification.—The rice plant possesses a very high degree of physiological adaptation to particular ecological factors, which is responsible for the fact that there are in cultivation several thousand different varieties of rice. According to Copeland, there are in India 8,000 varietal names given to probably different varieties of rice. But the number of distinct varieties is probably less, as the same variety may be given different names when grown in different localities.

The first attempt in the classification of rice in this country was probably made by Roxburgh who believed that the cultivated rices originated from the Indian wild forms which he found in Madras, Orissa, Bengal, the Arakan hills in Burma and Cochin-China. Roxburgh adopted a system of classification of rices based on their peculiarities of cultivation —the early and late rices.

Duthie and Fuller (1882) in classifying the rices of the United Provinces divided them into three classes. The first consists of those with a tall habit of growth, with protruded and drooping ears, and with a yellow-husked grain. The second group consists of those with shorter habits of growth, with ears not so prominent but more or less erect, and with thick yellow or red husked grain. The third group is made up of rices with short strong stems with the ears partially enclosed in the sheath and grain-husks dark-coloured or black. Hooker and Watt also made further attempts at classification of not only the wild rices but also the cultivated ones.

Gammie working in the Bombay Presidency made use of the average number of tillers in order to sort out the different varieties in the province.

Outside India, the first serious attempt at the classification of rice was made by Kikkawa (1912) in Japan, who used both the morpho-

logical and agricultural characters for separating the different varieties. Graham (1913), working in the Central Provinces, classified the rices of that region into two main divisions: (1) rices with coloured leaf sheath and (2) rices with green leaf sheaths. Then he further sub-divided each group into two sub-groups by the colour of their grain, that is whether red or white. Each sub-group was further divided on the basis of the (1) vegetative characters, (2) the character of the spikelet, and (3) the character of the grain.

In this way, Graham was able to sort out 100 different varieties of rice in the Central Provinces. Thadani and Durga Dutt (1928), in working with Sind rices divided them into two main groups: (1) bearded and (2) beardless, that is on the presence or absence of awns. The two main groups are further sub-divided on the basis of :—

'(*a*) Colour of leaf sheath—green or red.
(*b*) Colour of grain—white or red.
(*c*) Character of grain—long, fine or coarse.
(*d*) Colour of inner glumes—white, yellow, red or black.
(*e*) Colour or lack of colour of the tip of inner glumes.
(*f*) Colour or lack of colour of the outer glumes."

Thus Thadani and Dutt classified the rices of Sind into 35 different types.

Sethi and Saxena (1930) working with the rices in the United Provinces followed Kikkawa's system of classification, using both the morphological and agricultural characters for separation of the varieties. The system makes use of the character of the grain, such as its colour, size and shape. The different varieties, one hundred and thirty five in all, were then described by the character of the hulled and unhulled grain.

Mitra and Ganguli (1932) in classifying the rices of the Surma Valley in Assam used the characters of the unhusked grain for separating the varieties. The varieties were divided into two groups: (1) awned and (2) awnless. These were further sub-divided according to the character of the kernel, that is coarse, medium or fine, and whether they are glutinous or non-glutinous; and further whether the kernels are long, intermediate or short, and whether white, amber or red. The character of the inner glume is then used to further sub-divide the varieties, on the basis of whether it is yellow, brown, black or mottled.

These workers in Assam were able to classify the rices of the Surma Valley into 95 different varieties which are made up of 703 types.

Hector and his associates in Bengal made several attempts at classifying the rices of the province. The results of these efforts have been published from time to time since 1916. In his last classification published in 1934, all the varieties were separated into five main groups: (1) translucent, (2) glutinous, (3) winged, (4) clustered and (5) double-grained. These groups were further sub-divided according to whether the spikelet is awned or awnless, and whether the leaf sheath, tip and stigma are coloured or colourless "within varieties......types are further grouped into highland *Aus* and transplant *Amans*, according to date of sowing and harvest, and each of these again into early, medium and late, according to duration from sowing to harvest".

Thus Hector and his associates separated out 540 different varieties of rice in Eastern Bengal.

Kashi Ram and Chetty (1934) working with Bihar and Orissa rices based their classification mainly on morphological characters. The rices were divided into two groups based on the constitution of the rice grain, that is whether it is glutinous or starchy. Then they are further sub-divided according to (1) the length of the outer glumes, (2) the presence or absence of clustering in spikelets, (3) the length of the internodes, (4) the colour of the inner glumes, that is, whether brown, purple, black, olive, gold or straw coloured. Thereafter (1) the colour of the apiculus, that is whether it is colourless, purple or brown; (2) the colour of the outer glumes which may be white, brown and purple; (3) the colour of the kernel which may be white or red and (4) the colour of the internodes, whether green, gold or purple, are all used for further separation of the varieties. Finally the grain size and shape are used for separating the ultimate classes. In this way these workers sorted out 123 different varieties of rice in Bihar and Orissa.

Kashi Ram and Ekbote in 1936, published another classification of the autumn rices of the Punjab and the Western United Provinces using the same scheme used by Kashi Ram and Chetty in Bihar and Orissa. In this classification 41 different varieties of rice were sorted out.

Some other workers have started to classify rice from a genetical relationship, more particularly on the cytological evidence. Kato and his colleagues, working in Japan, have divided all the cultivated rices of the world into two types: (1) *japonica* which is indigenous to Japan and Korea, and (2) *indica* which is indigenous to India, China, Java, and south-eastern Asia. Thus the two groups may be called "temperate" and "tropical" rices. Cytological evidence shows that there is some difference in the nuclear structure as well as in the sizes of the chromosomes of the two groups. It has also been found by the above workers in Japan that there is some chromosomal incompatibility between the two groups. This is also supported by the work of Jones on Japanese and Chinese rices in California.

These different classifications evolved may serve as guides to the identification of the rices in the respective regions. But before a complete varietal classification can be made, a more detailed study of the cytological phenomena of the rice plant is required. It is also desirable that a complete botanical and agricultural survey of the existing varieties in India be made, before such a classification is possible. This can perhaps be done best by the establishment of a central rice research institute at some suitable locality. At such an institute all the varieties can be collected and grown for this purpose.

CULTURAL METHODS

Methods of Sowing.—While rice is sown in different parts of India, or even in the same regions, in different months of the year, yet the main bulk of rice is made up of the crop usually sown by broadcasting in April to May and usually known in Bengal as the *aus* "highland" rice, and another sown in June and July and usually transplanted into standing water in July and August and usually known in Bengal as *aman* "transplanted" rice. Besides these two major crops of rice, there are three others known in Bengal as the lowland *aus* rice, the lowland *aman* rice and the *boro* or spring rice. The following table shows more graphically the different agricultural characteristics of these five groups :—

Table XXIX

Showing the Agricultural Characteristics of Certain Groups of Rices.

Groups.	Sown.	Transplanted.	Harvested.
Aus highland ..	April—May .	Not transplanted .	August—September.
Aman transplanted	June .. .	July—August ..	November - January.
Aus lowland ..	February—March ..	Not transplanted ..	August—September.
Aman lowland ..	February—March .	Not transplanted ..	December—January.
Boro	October	December ..	March.

In Bihar and Orissa as well as in Assam the number of crops is more or less similar to that of Bengal.

In the United Provinces there are usually three crops of rice. The first is sown broadcast in the beginning of the rains in July. This crop occupies about 65 per cent of the rice area in the province. The second is transplanted rice, and is generally sown in the nursery in the first week of June and transplanted about a month later when the plants are about a foot high. This crop occupies about 35 per cent of the total area under rice in the province. The third crop is known as marsh rice and is equivalent to the *boro* in Bengal. It occupies a small percentage of the total area under rice in the province. The seed for this crop is sown in nurseries in the months of December and January and transplanted in February. It is commonly grown on the margins of lakes or ponds. The crop is harvested in May and June. This is therefore a *zaid* crop. The rice of this crop is usually considered to be of a poor quality.

When rice is broadcast, the land is generally prepared by ploughing and cross-ploughing as early as possible, preferably in the early winter before the soil gets too dry. When the early rain sets in, the soil is cultivated with a *bakhar* to pulverize the soil and to keep down the weeds. The clods are also sometimes crushed by means of a beam. When the monsoon sets in, the seed is broadcast or, better still, drilled into the soil to a depth of one or two inches.

When rice is transplanted, the seeds are first sown in the nursery, which is located where water is easily available. The seed bed is also prepared in a similar way as for broadcasting, but more care is taken in the preparation of the nursery as it is very important that the plants should have a good start. Usually the nursery is located on lighter soils so that the roots of the rice seedlings are not too seriously injured when removed from the soil for transplanting. One-tenth to one-twentieth of the area to be planted is required for the seed bed.

When the seedlings are about nine inches high, they are taken up for transplanting to the field. Before the seedlings are planted in the field the soil is usually flooded and puddled. The seedlings are then pulled and tied in bundles for transplanting. The tops of the bundles are usually cut off before transplanting is done. This trimming lessens transpiration through the leaves and also prevents them from being blown over by high winds before they take root. The number of seedlings put in at one point varies from one to four. Seedlings that are put in early usually grow better than those that are broadcast or even drilled. The seedlings are planted in rows as far as possible. The distance between rows and between points in a row varies with the variety, the distance between rows being usually about eight to ten inches, and in a row from six to eight inches.

Transplanting is usually done by women who walk backward in the soft mud and place seedlings about one inch deep in it.

In some parts of the United Provinces instead of transplanting, sprouted seeds are sometimes sown broadcast on well prepared puddled land.

The amount of seed necessary for one acre by broadcasting is about 30 seers; by drilling 20 seers; and for a seed bed, three maunds per acre may be sown, and this will be enough for twelve acres.

Care after Sowing.—When the crop is broadcast, usually no care is necessary until harvest, but if the fields are infested with weeds, ploughing is sometimes resorted to, when the plants are about a foot high. This inter-ploughing not only destroys the weeds but also some of the rice plants. The operation however is beneficial in that it stimulates the tillering of the plants.

Transplanted rice does not need very much attention after transplanting, except to see that the plants receive plenty of water

during the period of their growth. However the process of draining off water from the rice fields every week has been found to increase the yield of rice Uniform ripening of the crop is also brought about by draining the water completely well ahead of ripening stage.

Harvesting.—This is usually done by cutting the plants with a sickle, as in the case of wheat.

Aus paddy is usually harvested before the plants become quite mature as they shed the grain more easily than do the *amans*, and also because the stems are more brittle than those of the latter. The crop is therefore cut while the plants are still somewhat green, and then left in the fields for about a week to dry before the paddy is separated from the straw by threshing. After the crop has been harvested, it is collected in a heap and sometimes it is threshed by beating with a flail, but more often the ears are separated and the paddy is trodden out by bullocks. After threshing, the husk remains attached to the grain. These are separated later by pounding with a pestle in a mortar. It is usually advisable to defer the husking for a few months in order to decrease the amount of breakage in the process.

Where there is a large quantity of rice to be husked, this is generally done by means of a rice huller driven by some type of mechanical power. There are now several types of rice hullers on the market.

DISEASES AND PESTS

While the rice plant is more hardy and not so susceptible to diseases and pest attacks as wheat, yet there are a few that are of some economic importance. Those that are fairly common will therefore be discussed here.

Sclerotial disease (*Sclerotium Oryzae* Catt).—This is probably the most common fungus disease in the rice growing areas of India. The symptoms of this disease are not easily noticeable, and it is therefore generally overlooked The fungus attacks the plants near the base of the stems, causing them to bear what is known as "light" ears; that is, the ears contain about fifty per cent or less of spikelets which bear light grains The plants also throw out green shoots from the base when the rest of the crop is maturing and turning yellow. If the plants thus attacked are examined carefully at the base of the

stems, they will be found to be slightly discoloured at the lower internodes. If the stems are split at these internodes, a dark greyish web-like mass of hyphae is found within the hollow portion of the stem, and along with this small round black shining bodies can be found all over the inner surface. These bodies are known as sclerotia These sclerotia probably continue to live in the soil even after the crop is harvested. It is therefore extremely difficult to control a disease of this type.

False smut (*Ustilaginoidea Virens* (Cke.) Tak.).—This is another fungus disease which commonly occurs in certain parts of India, such as Bengal and Bihar. The plants attacked with this disease appear to bear some large green swollen grains, which are about twice the size of the normal grain. If the swollen grain is opened, the substance inside, will be found to be orange-yellow with a white mass towards the centre.

Usually the disease affects only a few grains in the ear, and these may be on any portion of it. Infection probably takes place during the flowering stage.

The disease is not yet completely understood and no control measure has been developed. However the disease is not serious, and hence control measures may be impracticable.

Bunt (*Tilletia horrida* Tak).—While this disease is quite serious in some parts of the world, in India it has not been found to do much damage. The disease however is known to be sporadic in nature.

This disease attacks the kernels, but the size of the grain inside the husk may or may not be increased, but never to the extent that the husk will be opened. Inside the husk of these diseased grains, a mass of black spores occurs within a thin membrane, which when ruptured sets the spores free.

The disease is controlled in America by floating out the light grains in cold water. These grains are usually the infected ones. The rest of the grain is then soaked for twenty-four hours in a solution of 1½ lbs liver of sulphur in 25 gallons of water, or by soaking the seed for two hours in a two percent solution.

In addition to the above diseases there are some which have been reported to do considerable damage in some localities. The

eelworm disease (*Ufra*) which is supposed to be caused by *Tylenchus angustus* is reported to have done a great deal of damage to rice in eastern Bengal. The life history of the disease has not been completely worked out and is therefore not completely understood.

Another disease which has been reported from Madras is said to be caused by *Helminthosporium* Sp. The fungus forms dark-brown disease spots on leaves, leaf-sheaths and glumes. The disease spreads rapidly when weather conditions are favourable for its development.

Rice hispa.—This is one of the most serious insect pests attacking the rice plant in this country. In the adult stage this insect is a black spiny beetle. It, however, does most of its damage in the larval stage. The damage done by this insect is mostly on the young seedlings in the seed bed or shortly after planting in the fields. The older rice plants are less attacked and usually not injured. The female adult lays its eggs in the young leaves, one egg at a time being deposited in the tissue under the epidermis. From this egg a grub hatches out which feeds between the upper and lower epidermis of the leaves causing the spot to turn yellow and wither. The grub is white or yellow with black markings, and is much flattened. The grub when full grown, turns into a brown, flattened pupa, and emerges as a beetle.

The pest may be controlled to some extent by bagging. This consists of dragging systematically a cloth bag which can be made of a *dhoti* held at two corners by two men. The beetles thus collected may be put in a pot containing water and little kerosene oil, so that they may die.

Another method recommended for controlling this pest is to drag a rope, across the field by two men holding at each end, the rope having been previously moistened with water containing kerosene oil. This should be done once in the morning and again in the afternoon to disturb the beetles and prevent them from laying eggs on the leaves of the young plants.

The rice leaf-hoppers (*Nephotetix bipunctatus* Fabr., and *apicalis* Motsch).—These insects have been known to do considerable damage to the rice crop in the Central Provinces, Bihar and parts of Assam. They belong to a group of insects known as the Jassids,

which are commonly found almost throughout India. These hoppers are small greenish insects which jump about from plant to plant. The adults remain on the lower surface of leaves mostly near the midribs sucking the juice during the hottest part of the day. Where the damage is serious, the fields appear blighted. These insects breed in succulent grasses in nurseries or near tanks, and begin to appear in large numbers in July. Heavy rains are unfavourable to their spread.

The adults are attracted to light, so the pest may be controlled by lighting small fires at night in several places in the fields. The insects will fly into the fire and burn themselves. These are usually noticed near the *Devali* festival when they fly to the *chirags* or small lamps in large numbers at night.

The rice grass-hopper (*Hieroglyphus furcifer* serv.)—This insect sometimes does considerable damage to the rice crop, by eating the leaves and the soft grains. The pest lives in the rice fields and occasionally in damp waste places or in sugarcane fields and generally appears in the months of August and September. It is a greenish or straw-coloured insect, which is found in two forms : one with long wings and another with short imperfect wings. But as the insect does not fly, the wings are apparently useless. The pest is commonly found in Bengal, the Central Provinces, parts of the Bombay Presidency, and Mysore.

The insect may be controlled by bagging or by dragging a net through the rice fields to sweep up the insect. Where the pest occurs every year, it is best to plough up the fields in April and May so that the eggs are killed by exposing them to dry heat. Also those birds that are known to eat these grass-hoppers may be encouraged by providing shelters for them in the rice fields.

The rice bug (*Leptocorisa varicornis* F.)—This is a slender green insect about three-fourths of an inch in length. These insects appear to be all legs and feelers with a long proboscis which reaches beyond the insertion of the hind legs. The insect possesses a peculiar odour. It does most of the damage to the rice crop by sucking the sap from the developing ears, causing them to turn white. The insect is commonly found in Assam, Bengal, the United Provinces and Madras.

The insect may be controlled by collecting in hand-nets or by bagging. The pest is controlled in nature by another insect known as the six-spotted tiger beetle (*Cicindela sexpunctata* L.) which feeds upon the rice bug

The army worm of paddy (*Spodoptera Mauritia* B).—This insect is common in many regions where rice is grown. In India it appears to be more common in the southern parts of the country such as the Madras Presidency, Mysore and the Nizam's dominions. The young caterpillar appears at the early stages of the growth of rice and usually does a great deal of damage to seedlings in the nurseries. The fullgrown caterpillars measure about an inch and a half in length. When the caterpillar is well fed it pupates and later developes into a moth. The insect is controlled in nature by birds and other parasitic insects The pest is also controlled mechanically by sweeping the insects with brooms into baskets or hand-nets. In some cases the fields are flooded and the insects come out of the ground, and are then destroyed by birds.

The rice weevil (*Calandra oryzae*).—This is a grain pest of stored rice, and has been discussed in the chapter on wheat.

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CHAPTER XIV

SUGAR CANE

Origin and History.—While the origin of sugar cane has not yet been definitely established, there is strong evidence that the Indian and tropical canes arose independently of each other in entirely different parts of the East. Barber was of the opinion that the Indian canes probably originated in the moister parts of India (Bengal and Assam) from some plant closely related to *Saccharum spontaneum* (Hindustani *kans*). He also concluded, mainly on the evidence of the Australian explorers, that the tropical class of sugar canes probably originated in some of the larger islands of Oceania, most probably in New Guinea.

The cultivation of sugar cane in India, according to existing records, dates back to the Hindu period, although it was probably in cultivation long before that. In Sanskrit the cane is *ikshu*, *ikshura*, or *ikshava* and the sugar is known as *sarkara* or *sakkara*. From India it probably spread quite early into China, Arabia and Egypt. After the Crusades it was introduced into Sicily, Portugal, the Canary Islands, and later into the New World. But even to-day the area devoted to sugar cane in India is greater than in any other country of the world.

Distribution in India.—The distribution of sugar cane in India according to provinces is as given in the following table.

TABLE XXX

Showing the distribution of sugar cane in India

Provinces and States.	Area in acres		Yield in tons of raw sugar.	
	1933-34	1937-38	1933-34	1937-38
United Provinces	1,713,000	2,127,000	2,532,000	3,101,000
Bihar and Orissa	418,000	{ 342,000 34,000	623,000	{ 356,000 63,000
Bengal	257,000	290,000	457,000	483,000
Punjab	466,000	512,000	364,000	363,000
Madras	122,000	98,000	349,000	279,000
Bombay	70,000	75,000	194,000	179,000
Hyderabad	46,000	30,000	72,000	60,000
Central Provinces and Berar ..	29,000	33,000	48,000	50,000
Assam	35,000	39,000	40,000	40,000
Others	155,000	..	215,000	..
Total ..	3,311,000	3,818,000	4,896,000	5,307,000

From the above table it will be noticed that the United Provinces is by far the most important sugarcane-growing province in India. But whereas the Punjab comes second in acreage, in the yield of raw sugar she stands fourth amongst the provinces.

Botanical description.—Sugar cane is a plant which belongs to the great family of grasses. But it is a tall perennial plant growing sometimes to a height of about 20 feet. It belongs to the genus *Saccharum* to which some of the most troublesome weeds of this country belong, such as *kans* (*Saccharum spontaneum*) and *sarpat* (*Saccharum arundinaceum*).

The stems of sugar cane are cylindrical, but they vary a great deal in size depending not only on the variety but also on the conditions of growth. While some varieties possess stems which are not much thicker than a lead pencil, other varieties, such as those found in the humid regions in Indo-China, may reach a maximum thickness of about three inches. The stem is jointed, that is, it possesses nodes and

internodes. A stem usually possesses 30 to 40 internodes but may sometimes possess as many as seventy. While most canes are thickened at the nodes, there are some that are thicker or more swollen at the internodes. Internodes possess certain characters which vary in different varieties. They possess, for instance, a groove which is a longitudinal depression extending upwards from the bud. This is present only in certain varieties, and when present it may extend over the entire length or only a portion of the internode. It may also be shallow or fairly deep. Another character which is found in these internodes is the presence of thin lines or small cracks in the epidermis which differ in nature, quantity and distribution. These lines or small cracks are known as ivory markings. Some varieties of canes also possess deeper cracks or splits in the epidermis. These also vary in number as well as in distribution. The shape of the internodes also varies with the variety. It may be straight-sided, barrelled, concave or convex.

At each node and alternately at opposite sides is a bud sometimes known as an "eye". This is an embryo shoot which makes possible the vegetative propagation of the cane. Although this structure is fairly small, yet it possesses certain characteristics which are sometimes of value in the identification of varieties. The most important of those characters are (1) the size and shape of the bud and (2) the flange which is the flattened edge of the bud formed by the outer bud scales. Just above the node is a ring of undeveloped roots which may develop into aerial roots or into permanent roots when placed in the soil. The outer surface of the stem is known as the rind which may be of varying colours such as green, red, purple, white, yellow or striped. Sometimes it may even be blotched with these various colours.

The roots of sugar cane, like those of all grasses, are fibrous, stretching in all directions. The depth to which they may penetrate depends mostly on the character of the soil and the amount of water in it. Although sugar cane is not considered to be deep-rooted, yet its roots sometimes reach a depth of 8 to 10 feet. During the sprouting of the sugar cane setts the roots begin to develop from the dormant root "eyes." These roots are known as "sett" roots and are temporary. After the emergence of the shoot from the bud, other roots are pro-

duced from the base of the shoot and are therefore known as "shoot" roots. These are the permanent roots, the "sett" roots usually dying in the early development of the plant. However, "sett" roots are essential for the development of the bud into the shoot. The extent of the root system depends on the development of other shoots from the main stalk.

The leaves of sugar cane, like those of grasses are made up of two main parts : the leaf blade (lamina) and the leaf sheath. The leaf sheath develops from the node and completely clasps the stem. The sheath may be colourless or pale-green and reaches a length of about 12 inches when fully developed. The sheath possesses certain characters which may be used in the identification of different varieties of sugar cane These are (1) the spines or hairs on the back of the sheath which are present in some varieties and absent in others, (2) the ligular processes which are lateral extensions of the sheath generally pointing upwards and developed at the junction of the sheath and the lamina, and (3) the ligule. The lamina may be two to three inches wide and three to four feet long. The leaves are usually green in colour, but the intensity of the colour depends on the variety. The midrib is usually whitish but may be reddish or purplish in some varieties.

The inflorescence of sugar cane is a panicle one foot or more in length with numerous branches borne at the end of the stem. It is long and tapering and is usually called the "arrow". The arrangement of the spikelets is racemose, that is, the oldest flowers are at the bottom and the youngest at the top. The spikelets occur in pairs one of which is pedicellate or stalked and the other sessile. At the base of each spikelets there is a tuft of long silky hairs, a character which has been used by some workers for the identification of varieties. Many seeds are infertile but when the fertile ones develop they are usually small and of low vitality. This is probably due to the fact that the cane has been so long propagated vegetatively by cuttings that it has nearly lost its fertility. Sugar cane usually flowers at 10 to 12 months of age, but some varieties do not flower, especially in Northern India.

Arrowing or the appearance of the inflorescence on sugar cane is popularly believed to have a detrimental effect upon the quality of

cane. Batham and Nigam working at Cawnpore (U. P.) report (1) that there is no evidence that arrowing reduces the tonnage of juice but that, on the other hand, it tends to increase it, (2) that arrowed canes have a higher sucrose content than non-arrowed ones at the time of the flowering of the former, and (3) that the glucose content of the arrowed canes is less than in the non-arrowed ones. Rao working in Coimbatore (Madras Presidency) has shown that arrowed canes deteriorate in quality after about 2½ months from the time of flowering, while there is a gradual increase in the sucrose content of the non-arrowed canes. Therefore, contrary to the general opinion, held by most farmers, flowering or the arrowing of the canes does not have a detrimental effect on the amount of sucrose contained in the plant. On the other hand, evidence seems to show that arrowed canes are earlier than non-arrowed ones.

Ecological factors.—Sugar cane will usually grow best on heavy soils, but will also do well on lighter soils where there is plenty of moisture and organic matter. In this country, the major portion of the crop, however, is grown in the Indo-Gangetic alluvium where the soils usually vary from loams to clays.

As sugar cane is a native of the tropics, its successful growth is in those regions where the climate is more or less tropical. That is, it will do best in regions which possess a warm climate. Under conditions in this country it has been found that cane growth starts when the mean temperature is about 68° F, the growth being more rapid as the temperature increases. The growth, however, stops at about 88° F, and its optimum growth is at about 78° F. The growth of the cane stops at about 65° F, and the bud is injured at about 52° F. Investigations in this country seem to show that those regions with an average mean temperature during the growing season of about 78° F, are best suited for the growth of sugar cane. The regions should also possess a fairly high humidity but with intervals of hot dry weather. Sugar cane also requires a long growing season. In most places in India its growing period is from ten to twelve months. A certain number of heat units is required to bring the plant to maturity. In colder regions, therefore, it will take a longer period to reach maturity as the number of effective heat units necessary for the plant to ripen is more or less similar in the two regions. The amount of rainfall

necessary for the optimum growth of the crop depends on the soil conditions as well as on the temperature. Where sugar cane grows under natural conditions, that is, without artificial irrigation, a deficiency of rainfall produces a fibrous cane; whereas under too heavy a rainfall the result is a cane of low sugar content. In this country sugar cane may be grown successfully in regions where the annual rainfall exceeds 55 inches.

Classification.—According to Jeswiet who has done extensive work with sugar canes in Java, the cultivated sugar canes with its probable ancestor are divided into groups as follows, grouped according to the distribution of hairs in the inflorescence :—

A. Main axis of the inflorescence carrying long hairs.

B. Lodicules ciliate.........*Saccharum spontaneum* (*Kans*)

This is a wild form.

B. B. Lodicules non-ciliate.

C. Leaves broad...........*S. Sinense* { *Pansahi.* *Nargori.* *Mungo* (*Uba*).

CC. Leaves narrow.........*S. Barberi* { *Saretha* *Sunnabile* } Saretha and Chunnee.

AA. Main axis of the inflorescence without hairs ....
S. Officinarum (The Noble canes).

The *Pansahi* group probably has the widest distribution in this country as it occurs in the whole region extending from the Punjab to Burma, although it is not grown in the peninsula. The group is represented by *Kahu* in the Punjab, and by a cane known as *Uba*. In size it is intermediate between the thick and the thin canes and is usually known as *ganna*. The branching of this group of canes is usually symmetrical; the inner canes usually are straight and the outer ones are curved, giving the clump a cup-shaped appearance. The internodes of these canes are usually long and more or less zigzag in appearance, and the nodes are prominent.

The *Nargori* group is not so common as the *Pansahi* group in northern India. It occurs to some extent in Bihar, the United Provinces and the Central Provinces. The canes are straight and thin and possess well-marked bloom bands, and are strongly noded. The stem

colour is usually brownish or copper coloured in northern India. The group is easily distinguished from the others by its palm-like habit; that is, the canes are surmounted by short and broad leaves. The group as a whole matures early.

The *Mungo* group is also fairly common in northern India. The canes are short, somewhat thick and straight or slightly curved, and usually possess green stems which sometimes develop delicate rosy tints in northern India. The stems are also uniform in thickness, with short internodes and without prominent nodes. The "eyes" or buds of this group have blackened flanges. In habit the plants of this group are usually dwarf and bushy, but this character varies within the group and with the locality. The canes usually possess a uniform mass of drooping leaves, with narrow blades or lamina and long sheaths.

The *Saretha* group occurs in most parts of India, and is represented by *Katha* canes in the Punjab, *Chin* and *Saretha* in the Western United Provinces, *Kahri* in Bengal and *Hullu Kabbu* on the western coast of the peninsula and *Ganda Cheni* in Mysore. Those occurring in northern India are usually thinner-stemmed. The group has been divided into two sections: (1) those possessing reddish brown stems at maturity and (2) those with green stems at maturity. The *Katha*, *Chin* and *Saretha* canes fall in the first section, while the *Khari*, *Hullu Kabbu* and *Ganda Cheni* are in the second. The green ones are very similar to those in the Sunnabile group. The canes of the reddish brown section usually grow more rapidly than those in the other section.

The canes of this group may be distinguished from those in the others by the irregular and more or less prostrate habit of growth. The canes of this group grow in different directions and sometimes may even lie flat on the ground. The stems of these canes possess long internodes which are more or less zigzag, but of uniform thickness. The leaves are often sharply bent near the tips. The group as a whole is early maturing.

The *Sunnabile* group is very widely distributed, as representatives of this group grow in most parts of the country extending from the Punjab to Assam and also in Madras. The group is represented by *Dhaulu* in the Punjab, *Mojora* in Assam, *Dhor* in the Central Provinces, *Sunnabile* in Bombay and *Naanal* in Madras. The stems are

usually straight and regular without prominent nodes, soft, and often white in colour. The branches are few and the clumps are close and upright

The Noble canes are thick canes commonly known as *paunda* in northern India. They are commonly grown for chewing purposes. They require intensive cultivation and are more susceptible to mosaic. They contain a higher percentage of sucrose than the *desi* (local) varieties.

The improvement of sugar cane in this country practically began in 1912 when the central sugar cane breeding station was started at Coimbatore, on the recommendation of the Board of Agriculture in 1911. The station was started to produce improved canes for every part of the country. One of the reasons for the selection of a place in South India is that most of the sugar canes produce flowers and viable seeds under the conditions existing there. And as most of the sugar cane area in this country is in North India, so most of the work done at Coimbatore was to produce varieties suitable for conditions in northern India. In the course of a quarter of a century, this station has done very valuable work and has successfully introduced certain varieties which are rapidly becoming popular in northern India.

As a result of investigations of the Coimbatore varieties in the farms in the United Provinces during the last few years, the following are some of the canes now recommended by the Agricultural Department to the cultivators in different parts of the province.

Co. 213.—This has been the standard cane of the province for several years, especially in the eastern, north-eastern and the central areas, but its performance during the last few years has not been as good as some of the newer Coimbatore varieties. However, in the Rohilkhand and Kamaun circle, experiments on the Nawabganj farm seem to indicate that this cane is still as good as the others.

The cane was probably a cross between P. O. J. 213 (female parent) and *Kansar* (male parent). This is a cane of medium thickness and is erect in habit although more or less depressed at the early stages of its growth. It is a soft cane but not too soft, and is not likely to lodge. It is susceptible to but tolerant of mosaic. The colour of the stem is somewhat yellowish and with a green tinge on

the upper portions of the internodes. The growth ring is yellowish to brownish. The shape of the internode is barrelled with a slight bulge on the side opposite to the bud. The groove may be present, but if present, is not prominent. Ivory markings may occur but splits are altogether absent. The bud is of medium size, more or less round in shape and plump. The flange is often prominent, rising at about the middle of the bud and is of almost uniform width throughout. The cane contains about 63 per cent. juice, whereas the sucrose in the juice is generally 15 per cent.

Co. 290.—This cane is a cross between Co. 221 (female) and D. 74 (male). This has been for some years a standard cane in the Meerut and Rohilkhand divisions. The cane is soft and is therefore easily crushed. This character of the cane however makes it more susceptible to attacks by wild animals. It is a weak cane and therefore lodges easily. The juice to cane ratio is 66·5 and the sucrose content in the juice is about 15·7 per cent. This cane, however, is now beginning to lose its popularity.

Co. 312.—This is a cross between Co. 213 (female) and Co. 244 (male). This cane, in many of the experiments in the United Provinces, has proved itself to be superior to almost all the other Coimbatore varieties introduced in the province. It is expected therefore that this cane will gradually spread in many districts where it has been found to do well. This is a soft cane, which tillers well and can stand unfavourable weather better than other varieties. The internodes are of medium thickness and usually 3 to 4 inches in length. The leaves are abundant and of medium width. The cane ripens fairly early.

While this cane possesses good agricultural characters, it has been found to be susceptible to lodging on rich lands. Its sucrose content varies from 13·26 to 16·59 per cent.

Co. 313.—This is also a cross between Co. 213 (female) and Co. 244 (male). It is a medium cane with a soft, green rind. The internodes are rather long, usually about 5·7 inches in length. The cane can stand hot weather well. In habit it is semi-erect, but open at the early stages. It does not lodge easily, and possesses numerous tillers. It grows well under humid conditions. The cane, however, is suscepti-

ble to mosaic. Its sucrose content is high, reaching about 19·5 in February in Bihar.

Co. 331.—This cane is a cross between Co. 213 (female) and Co. 214 (male). It is a tall growing variety with medium thickness and with a medium hard rind. The internodes are quite long, being usually about 6 to 8 inches in length. It can stand hot weather successfully and does not suffer seriously during periods of drought. It is erect in habit and rapid in growth. It also tillers well, and does not usually lodge. The leaves are long, erect and tough. Its sucrose content is also high reaching about 17 to 18 per cent.

Co. 356.—This is one of the sorghum-sugar cane (*jowar*-sugar cane) crosses recently produced at Coimbatore. The other members of the series are 351, 352, 353, 354, 355 and 357. Of these 356 seems to be the most promising. This variety seems to do best in the North-Eastern Circle of the province. The variety is early-maturing since it is a cross with *jowar*, and is also expected to require less water and also to stand unfavourable conditions better than other sugar cane varieties. The sucrose content of this cane is 16·11 (Pusa analysis).

Besides the varieties mentioned above, other Coimbatore varieties such as Co. 301, Co. 300, Co. 370, Co. 349, Cos. 51, Cos. 19, Cos. 23, Co. 393, have been tried and so far results with regard to these varieties have not been very conclusive.

In the Punjab area the Coimbatore varieties have of late become very popular, so that they now occupy an area of about 44 per cent of the total area under sugar cane. The following Coimbatore varieties have more or less established themselves since they have been introduced into the province. Co. 205, Co. 213, Co. 223, Co. 300 and Co. 312.

Co. 205.—This is a cross between a sugar cane known as *Vellai* (female) and *Saccharum spontaneum* or *Kans* grass (male). This is a thin cane which generally stands erect but will be crawling or slightly curved under marshy conditions. The cane is very hardy and therefore can stand unfavourable conditions fairly well. Its juice content, however, is low. In heavy soils the cane tillers well. Its growth during the rains is very rapid. The cane splits badly, almost at every internode. The colour of the stem is glaucous green with a tinge of yellow at the base of the internodes. The internodes are straight-sided,

The bud is small to medium, generally obovate and flat. The flange in the bud is not consqicuous.

Co. 223.—This is probably a cross between *Chittan* (female) and *Naanal* (male). It is a medium cane with an erect habit. The colour of the cane is a light pinkish purple appearing ashy on account of the overlying waxy layer. The root zone is whitish but the growth ring is yellow. The stems are thinner in the upper portion of the internodes, with a moderate amount of ivory markings, and the splits are few.

Co. 300.—This cane is a cross between Co. 213 (female) and P.O.J. 1410 (male). It is a medium thick cane, straight-sided with medium hard rind. The internodes are about 4 inches in length and splitting is absent. The lower nodes sometimes develope aerial roots under humid conditions. The cane suffers under continuous drought. The cane also does not lodge easily. The sucrose percentage of the cane is about 17 per cent.

Besides these five Coimbatore varieties, the province also grows to some extent certain local varieties such as *Lalri*, a thin cane, *Katha*, an indigenous cane of the Punjab, *Suretha* which is a thicker, softer and whiter cane than *Lalri, Dhaulu*, a white soft chewing cane and *Bodichin*, the latter two being usually grown under *barani* conditions.

In Bihar and Orissa the most promising of the Coimbatore varieties seem to be Co. 331, Co. 318, Co. 313, Co. 312, Co. 301 and Co. 299.

Co. 331.—This is a very promising cane in the conditions where it has been tried in Bihar, and has therefore been highly recommended to the cultivators. It is also one of the canes recommended in the United Provinces and has therefore been described with the U. P. canes.

Co. 318.—This cane has resulted from the selfing of Co. 229. It is a medium thick cane with a very hard rind. In habit it is straight and erect and stands thick and uniform in most types of soil. It tillers freely. Its leaves are abundant. It is claimed to be flood resistant, and is likely to tolerate *usar* conditions to some extent. The cane does not lodge even with strong winds, and may even be used as a wind-break for other varieties of cane. It ripens late in Bihar.

Co. 313.—This is an early cane in Bihar and is preferred by the mills on account of its high sugar content and is liked by the cultivators because of its high yield. This cane is also one of those recommended for certain areas in the United Provinces and was therefore discussed in that section.

Co. 312.—This cane has been recommended for regions in south Bihar, as its yield in that area is fairly high. This is one of the most highly recommended canes for the United Provinces, and has already been discussed.

Co. 301.—This is a cross between Co. 213 (female) and P. O. J. 1399 (male). It is a medium thick cane with a medium hard rind, and ripens between the early mill varieties and the mid-season ones. In habit it is semi-erect to erect at maturity, but susceptible to lodging. It stands drought well but tillers badly in light soils. It grows well in the humid weather but is susceptible to top-rot. This variety is also considered to be highly resistant to floods.

Co. 299.—This is a cross between Co. 213 (female) and P. O. J. 1410 (male). It is early, ripening in about November and has therefore been distributed as an early mill cane in north Bihar. In habit the cane is generally erect but slightly curved towards the top. It has a slow and bushy growth but grows rapidly during the rains. It stands the hot weather fairly well. The cane however does not tiller well and is susceptible to lodging.

CULTURAL METHODS

There are three different methods of planting sugar cane commonly used.

1. Planting on the level or on the flat.
2. The "ridge and furrow" method.
3. The trench method of planting, sometimes known as the Java method.

1. In the first method the land is simply ploughed, rolled and levelled. The cane setts are then planted on the level and covered with soil to a depth of about two inches only. The setts are placed end to end in rows which are about 2½ to 3 feet apart. This practice is generally followed when there is abundant moisture in the soil.

2. The ridge and furrow method consists of planting cane setts in furrows which are $2\frac{1}{2}$ to 3 feet apart, depending on the variety of cane, the former distance being usual for the thin canes and the latter for the medium thick ones. The depth of the furrow depends upon the kind of soil and season of planting. The furrows are usually opened with a double mould-board plough.

The cane setts may be placed end to end in a furrow, but when cane with long internodes is planted, such as the Coimbatore canes, it is preferable to plant the setts eye to eye. This will decrease "gappiness" or the number of gaps in the rows. In order to ensure a good stand at the end of the furrows it is also advisable to plant double setts for about two yards. The doubling of the setts at the ends is necessary on account of the unfavourable effects on borders. After the setts have been placed in the furrow a gatherer and roller is drawn over the furrows in order to fill them up and to cover and press the setts.

3. For trench cultivation the land is ploughed immediately after the *rabi* crop is harvested, and then left fallow during the hot weather. The land is ploughed as many times as practicable during the rains. The trenches are then made during the month of October or November, but the operation should be finished by the end of November, as the soil has to be exposed to the weather in order to give the best results. The trenches made for thick and medium canes are two feet wide and 4 feet from centre to centre. The trenches are dug 6 inches deep and the soil is placed on the two-foot space left between trenches. After the trenches are made, the soil in the trenches is stirred up to a depth of about 9 inches and the soil is thoroughly mixed with the manures or fertilizers that are to be applied in the trenches. The trenches are then ready for planting.

The setts may then be placed in the middle of the trenches and are pressed down in the soft soil and finally covered with soil to a depth of about 3 to 4 inches. If there has been no rain previous to planting, the trench should be irrigated about two or three weeks before planting and the soil should then be stirred with *pharwas* (hoes) just before planting.

As sugarcane setts are usually attacked by white ants, it is advisable to treat the setts before sowing. This is done by dipping the setts

in a mixture of water and coal tar at the rate of 10 drops of coal tar to a gallon of water. This mixture should then be boiled before using. When the mixture is cool the setts are immersed in the mixture and planted immediately. In adopting this method one should see that no tar remains free in the mixture as it may injure the "eyes" or buds.

In places where sugarcane smut is common it is sometimes desirable to immerse the setts in Bordeaux mixture in order to prevent the occurrence of smut or some other fungous diseases. The selection of healthy canes for setts is also important where mosaic and red rot are common.

The amount of seed per acre varies with the method of planting, the variety of cane, distance between rows, etc. When the setts are planted eye to eye, more seed will be required per acre than when planted end to end. The number of setts also depends on the length of the internodes in the cane. A sett is usually a piece of sugarcane stem containing two or three buds or "eyes". Using the trench method of planting the amount of seed required per acre is about 60 maunds of thick cane and 40 maunds of medium cane when stripped or approximately 1600 to 2000 canes.

Cultivation after sowing.—Cultivation or the constant stirring up of the soil is of primary importance with sugarcane. The first two or three hoeings are done even before the plants have appeared above the ground. During this operation, which is generally done by *pharwas*, care must be taken not to injure the shoots which may be coming up through the soil. When the canes are planted in trenches, these are gradually filled with earth when the canes have attained a height of about 2 to 3 feet above the ground. After the trenches have been filled in and before the rains begin, it is necessary to earth up the canes. This is essential in order to reduce the amount of lodging in the crop. After this, very little attention is required in the way of cultivation during the monsoon.

Irrigation.—Sugar cane is a plant that requires plenty of water. So in most parts of India, where rainfall is not sufficient to mature the sugar cane crop, artificial irrigation becomes necessary. Mollison in Bombay claims that an irrigation of about 80 inches throughout the growing period with an average rainfall of about 30 inches is just sufficient to mature a crop. Roberts and Faulkner in the Punjab also

estimate that an irrigation of about 80 inches is necessary for thick canes and 50 to 60 inches for thin canes. However the amount of irrigation water required depends on the amount of rain received, the type of soil and the variety of cane. The number of irrigations generally given may therefore vary from 7 to 12 during the whole period.

Manuring.—Sugar cane is a crop that requires heavy manuring. The amount of nitrogen usually required for a good crop of sugar cane is from 150 to 200 lbs. per acre. However, in the case of organic manures (especially animal manures), it is not desirable to apply them directly to the crop, as this may attract white ants or delay ripening. When green-manuring is practised, crops of *dhainchia* (*Sesbania aculeata*) in Bengal and Madras, sann-hemp (*Crotolaria juncea*) in Bihar and the United Provinces and *senji* (*Melilotus parviflora*) in the Punjab are generally grown in the *kharif* season previous to the planting of sugar cane. The green crop is then ploughed under some time before the preparation of the land for the sowing of sugar cane.

Other organic fertilizers commonly used in connection with sugar cane are farmyard manure usually applied at the rate of 20 to 30 cart-loads (400 to 500 maunds) per acre. This manure is usually applied soon after the trenches are dug, and mixed in thoroughly with the soil in the bottom of the trench. This type of manure is applied at this time in order to allow sufficient time for its decomposition to take place; otherwise, white ants may be attracted by the undecomposed manure. Castor cake or mustard cake is usually applied at the time of planting at the rate of about 7 maunds per acre.

Some of the commercial fertilizers that may be applied profitably to sugar cane in India are ammonium sulphate and superphosphate. Chilean nitrate also has been used but does not give results as good as those of ammonium sulphate. It also seems very probable that the application of large quantities of available nitrogen tends to reduce the quality of the cane for gur-making. This type of manure is usually applied after first ridging up the young plants. The method of application of these fertilizers consists in putting in spoonfuls of the fertilizer with small wooden spoons in holes dibbled on ridges near the stools. Then the holes are covered up and pressed with the foot. The advantage in applying it in this way is the reduction in the loss of the fertilizer which may be caused by leaching.

Tying and trashing.—Most varieties of canes which possess soft rinds frequently lodge and therefore need tying up. This practice is also beneficial as it minimizes the damage from insect and disease attacks, and makes the growth of canes uniform and clean. This may be done by tying together the canes of several clmups. The outside canes are sometimes propped by tying a stout string or wire all round the field of sugar cane.

Another method of minimizing lodging is known as "trashing". This consists in the removal or tearing away of the older leaves as the canes grow. While this practice has been found to be advantageous in places where high winds commonly occur, in other places it has been found to be disadvantageous as the scars formed by trashing afford good resting places for the development of the spores of fungi.

Harvesting.—When the canes are mature, which condition is generally recognized by the withering of the top leaves, the crop is fit for harvesting. Ripeness may be further confirmed by testing the sweetness of the canes.

Harvesting is usually done by cutting with sickles as close to the ground as possible. The canes are then stripped and topped and then tied in bundles, ready for transportation.

Ratooning.—When the root-stocks from which the canes have been removed are left in the soil, a new growth of canes is produced. The canes produced in this way are known as "ratoons", and the crop grown in this way for the first time is known as the "first ratoon"; and if this process is repeated for the second year, the crop will be known as the "second ratoon"; and so on. Sometimes this process is continued for several years, but in India this practice is not common. The introduction of Coimbatore canes, however, has made this practice more popular in certain cane areas in the Punjab. While this method does away with the operation of planting cane for as long as it is continued, it has been found that the continuous growing of the crop by ratoons steadily diminishes the yield, so that it makes the practice usually unprofitable. In general, for most soils, it is not advisable to grow more than the second ratoon. The practice has one more serious disadvantage in that the crop is on the land continuously, allowing favourable opportunities for the development throughout the year of the numerous insect pests and diseases which prey on the crop. Ratooning is inadvisable in this country where red rot of sugar cane is common.

DISEASES

Sugar cane has a very large number of enemies in the form of fungi, insects and even animals. Some of the most common diseases and pests which attack the sugar cane crop in this country will be dealt with here.

Red rot—(*Colletotrichum falcatum* Went).—This is probably the most common disease not only in India but in other cane-growing countries as well. In India it is found almost everywhere where sugar cane is being grown.

The disease usually shows no sign of its occurrence until the canes ars seriously affected. The first external sign of this disease is that the upper third or fourth of the leaves of the shoot begin to show signs of yellowing and withering. The edges of the leaves thus wither, leaving the centre green. Finally the whole top withers and droops as if affected by drought. On splitting the stems open, it will be found that the tissues inside are irregularly coloured red in streaks, these streaks or bands usually extending out from the region of the nodes. The characteristics of this disease is the appearance of white blotches surrounded by the red tissue. In the white spots a mould is always present, a few threads of mycelium being found in the red patches.

The reddened tissues which are caused by this disease are more commonly found near the base of the stems. The reddening in the later stages may change to brown or light brown colour. The disease is usually accompanied by a sour smell which may be detected when the diseased canes are split open during the early stage of the attack

The damage by this disease to sugar cane in India is very great, and therefore control measures should be adopted to prevent it. The preventive measure against this disease is the planting of healthy stock. In areas where this disease is common it would be well to bring healthy seed canes from outside. It has also been found that the thin canes of India are less susceptible to red rot than the thick ones.

The introduction of canes that are less liable to the attack of this disease will, to a large extent, successfully control the prevalence of this disease.

Mosaic.—Sugar cane mosaic is probably caused by an ultra-microscopic particle known as a virus. This is much too small to be

seen even with the highest-powered microscope. It is estimated to be some forty times smaller than a bacterium whose size is about twenty-five thousandth of an inch in length. Research workers are not yet agreed as to whether a virus is living or non-living or even intermediate between these two states of matter.

Sugar cane attacked by this disease shows a mottled appearance in the leaves, that is, light coloured patches alternate with green. These light-coloured patches are elongated and run parallel to the axis of the leaf. The mosaic patterns on different varieties of sugar cane differ considerably. These mosaic areas cover practically the whole of the leaf blade in severely diseased plants. The disease however is not so easily distinguished in the thin canes.

The agent causing the disease is believed to be carried from plant to plant by insects. Such insects as *aphids*, *jassids*, and grasshoppers are definitely known to spread virus diseases. Although the plants attacked by this disease are not killed, yet it has been found that there is a reduction in the yield as well as in the sucrose content of the canes.

The disease in India may be controlled to some extent by growing mosaic resistant varieties. Luthra and Sattar, working in the Punjab, report that certain varieties such as *Lalri*, *Kahu*, and *Kansar* as well as a number of the Coimbatore varieties such Co. 314 did not show any incidence of mosaic. The following varieties however varied in their infection by mosaic, from 5 to 20 per cent. Co 313, Co. 300, Co. 213. Among those which showed more than 20 per cent. infection was Co. 205. In general it appears that the thin canes are less susceptible to the attack of mosaic than the thicker varieties.

When the disease has appeared in the field the affected plants should be removed and burnt.

Smut (*Ustliago sacchari* Rabenh).—This disease is found in all parts of India. The disease can be easily recognized by the black whip-like projection which appears on the top of the shoot, and is several feet in length. This shoot is leafless. The disease is more prevalent among the thinner varities of cane such as Saretha, Sunnbile and *Katha*. The manner in which the disease spreads is not definitely known. It is believed that it may be transmitted through setts from infected canes. The disease however is not known to do very serious damage.

The best methods of controlling this disease seems to be the removal and destruction of the affected plants by burning, and by growing only those varieties which are known to be resistant to the disease.

Brown leaf spot (*Cercospora longipes* Butl.)—This is a very common sugar cane leaf disease in this country, but it is confined largely to the thin canes. The disease is known by the narrow oval spots about 1/8 inch long and of a reddish colour. Upon full development the red spots develop brown centres. The spots may be seen on both surfaces of the leaf. When the attack is serious it imparts a reddish tinge to the foliage. While the disease does not kill the plants, nevertheless it injures the leaf surface and thereby reduces the yield of sugar. At present, no practical method of treating this disease is known.

Other diseases which sometimes are found to damage sugar cane plants are sugar cane wilt (*Cephalosporium sacchari* Butl.), collar rot (*Hendersonina sacchari* Butl.), eye spot (*Helminthosporium sacchari* Butl.), sooty mould (*Capnodium* sp.), ring spot (*Leptosphaeria sacchari* van Breda) and rust (*Puccinia Kuchnii* (Kr.) Butl.).

INSECT PESTS.

The Sugar cane stem borers (*Argyria sticticraspis. Chilo zonellus* and *Diatrea venosata*).—All these three insects are very much alike in all their stages of development. The nature of their damage to sugar cane is also the same. All the three insects are moths in the adult stage. But they do most of their damage to sugar cane in their larval stage, when they are known as caterpillars. The eggs are usually deposited on the lower surface of the leaves in clusters of about twenty. These eggs hatch into caterpillars which are pinkish in colour with black heads and short dark spines. These caterpillars in their early stages feed on the leaves and later bore into the stems which they hollow out, thus interfering with the circulation of the sap, and causing what are generally known as "dead hearts". A complete cycle of these insects takes about 6 weeks during the hot weather.

The borers may be controlled to some extent by the following measures :

1. As the insects are attracted to light they may be collected in light-traps placed on dark nights in and near the affected fields.

2. Only unaffected setts should be planted.

3. Ratooning should be avoided in places where these pests are common.

4. As these pests also attack maize, and *jowar* it is advisable to pull out all affected plants of maize, *jowar*, and sugar cane early in the season and destroy them.

The sugar cane hispa (*Asmangulia cuspidata*).—This is rather a small insect about one eighth of an inch in length, black in colour, with characteristic black spines on the body. Most damage to sugar cane by this insect is done by the larva of this beetle known as the grub. The grub tunnels into the leaves which turn brown or light-coloured. The grub, when full-grown, pupates in the tunnel and emerges as a beetle. In North India three to four generations are produced in the course of a year, but they are most common during the monsoon.

The pests may be controlled to some extent by catching them with hand-nets. Affected leaves also should be removed and burnt.

The sugar cane leaf-hoppers (*Pyrilla pusana, P. aberrans and P. perpusilla*).—These three species of insects are very similar in appearance and habit. The adults are small active insects about one-third of an inch in length. The adults as well as the nymphs jump about quickly from place to place if disturbed. The young ones are pale brown in colour and the adults possess brownish wings. The young ones take about two months before they reach the adult stage. The damage to sugar cane by these insects is done both by the young and the adults by sucking the juice from the leaves.

The pest may be controlled by collecting the eggs which will usually be found in a mass covered with filamentous white material and which shows up conspicuously against the green back-ground of the leaf. This mass of eggs is found on the lower surface of the sugar cane leaf. Or the leaves containing the eggs may be removed

and destroyed. The pest may also be controlled by bagging the adults with hand-nets and destroying them.

The white ants or termites.—Termites, commonly but incorrectly called "white ants," are responsible for a great amount of the damage done to the sugar cane crop in this country. In their attack on sugar cane they usually begin at the roots and work towards the main stem, until the plant withers and dies. The damage is usually worse in loams than in stiff clays.

One of the methods used in the control of white ants is the use of irrigation water charged with crude oil emulsion at the rate of 5 seers per acre. The best way to apply it is to place the emulsion in a gunny bag and place it in such a way that the under surface of the bag just touches the water in the irrigation channel. This method does not destroy the white ants but drives them away; hence it may be necessary to repeat this process two or three times during the season.

Some of the **minor pests** of sugar cane are the mealy bugs (*Pseudococcus saccharifolii* Gr. and *Trionymus sacchari* (Ckll.), the cane white-fly (*Aleurolobus barodensis* Mskll.), the top shoot-borer *Scirpophaga nivella* Fabr.), and the root-borer (*Emmalocera depressella* Swinh.)

Sugar cane is also sometimes subject to the attack of a flowering plant which is partially parasitic on the roots and is known scientifically as *Striga lutea*. The parasite sends out its roots which branch very extensively forming a network of fine rootlets which entwine the roots of the canes. The canes thus attacked remain stunted and appear as if they were affected by drought. The plant itself possesses leaves, by which it can manufacture part of its food, and is therefore not altogether dependent on the host on which it is para itic. The plant also possesses several branches on which it bears flowers and produces seeds.

The only method of controlling it is probably by preventing it from going to seed. Where the land is badly infected with this weed, sugar cane as well as *jowar* should not be grown for some years, as these two crops are known to be host plants to this parasite.

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CHAPTER XV

COTTON

Origin and history.—Cotton has been used in this country as a fabric from time immemorial. The first reference on record to the use of cotton in this country was that found in the Rig Veda. Cotton was also mentioned in the Laws of Manu. The use of cotton, therefore, for weaving, must have been known for generations before these records.

Recent work on cotton has shown that there are at least three different groups of cottons, based largely on the chromosomal and genetical behaviour, with different centres of origin. The first group consists of the wild and cultivated cottons of the Old World with 13 chromosomes. These are the species arboreum and herbaceum of the Old World. The latter is believed to have originated in Africa, whereas arboreum developed in the continents of Africa and Asia. The second group include the wild cottons of the New World also with 13 chromosomes. These are indigenous to the western coasts of the United States of America and Mexico. The third group is made up of the cultivated American cottons and three wild species from islands in the Pacific, with 26 chromosomes.

Distribution in India.—While cotton is grown in almost all parts of India, it is mostly grown in the black cotton soil area of the country, and also to a considerable extent in the upper parts of the Indo-Gangetic alluvium and Sind. The following table shows the distribution of cotton in India according to provinces and states

TABLE XXXI

Showing the distribution of Cotton in India.

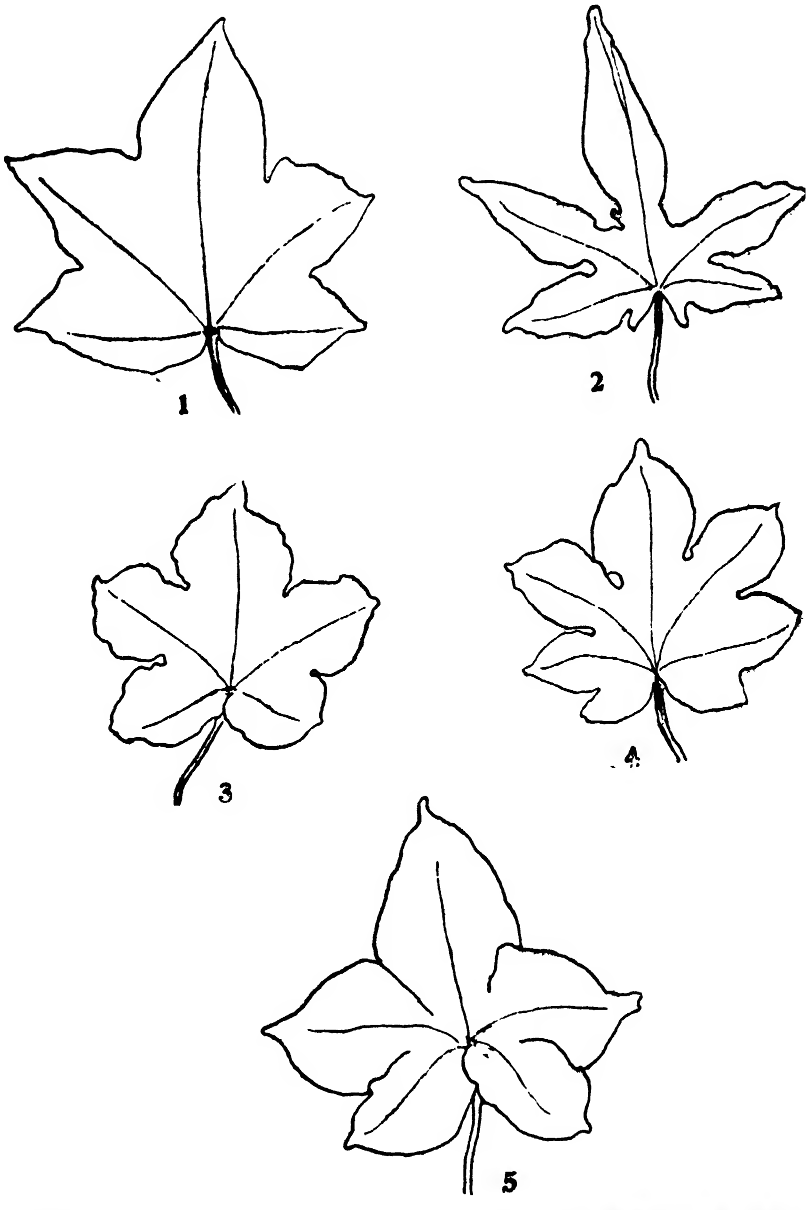
Provinces and States	Area in acres in		Yield in 400 lb, bales in	
	1933-34	1937-38	1933-34	1937-38
Punjab	2,449,000	3,135,000	927,000	1,140,000
Central Provinces and Berar ..	4,270,000	4,047,000	758,000	711,000
Bombay	3,655,000	3,862,000	638,000	734,000
Bombay States	2,222,000	2,312,000	587,000	479,000
Hyderabad	3 696,000	3,563,000	564,000	579,000
Madras	2,156,000	2.569,000	450,000	504,000
United Provinces	805,000	567,000	265,000	193,000
Sind	570,000	970,000	186,000	354,000
Punjab States	540,000	851,000	178,000	373,000
Central India States	1,152,000	1,337,000	154,000	143,000
Baroda	731,000	914,000	90,000	186,00
Rajputana States	493,000	524,000	65,000	63,000
Gwalior	614,000	668,000	59,000	78,000
Bengal	58,000	58,000	21,000	23,000
Others	726,000		166,000	..
Total .	24,137,000	25,741,000	5,108,000	5,660,000

Botanical description.—The cotton plant belongs to the *Malvaceae*, or mallow family, to which other economic plants such as *bhindi* (*Hibiscus esculentus*), roselle or *patwa* (*H. sabdariffa*), and *patsann* (*H. cannabinus*), belong. The genus *Gossypium* to which cotton belongs contains several species which are both wild and cultivated. The number of indigenous cultivated species in India, according to a recent classification, is only two, namely *G. herbaceum* and *G. arboreum*, which are sub-divided into several "forms" or varieties.

The cotton plant is shrubby, herbaceous or tree-like, and in the wild state under tropical conditions it is perennial, but most of the

cultivated cottons in the world today have developed into annuals. Under cultivation the plant is a much branched, more or less herbaceous shrub, growing to a height of from two to six feet.

The main **stems** are erect and branching. The **branches develop** from buds located at the nodes of the main stems. The branches are of two types. (1) the *vegetative* (monopodial) branches and (2) the *fruit*



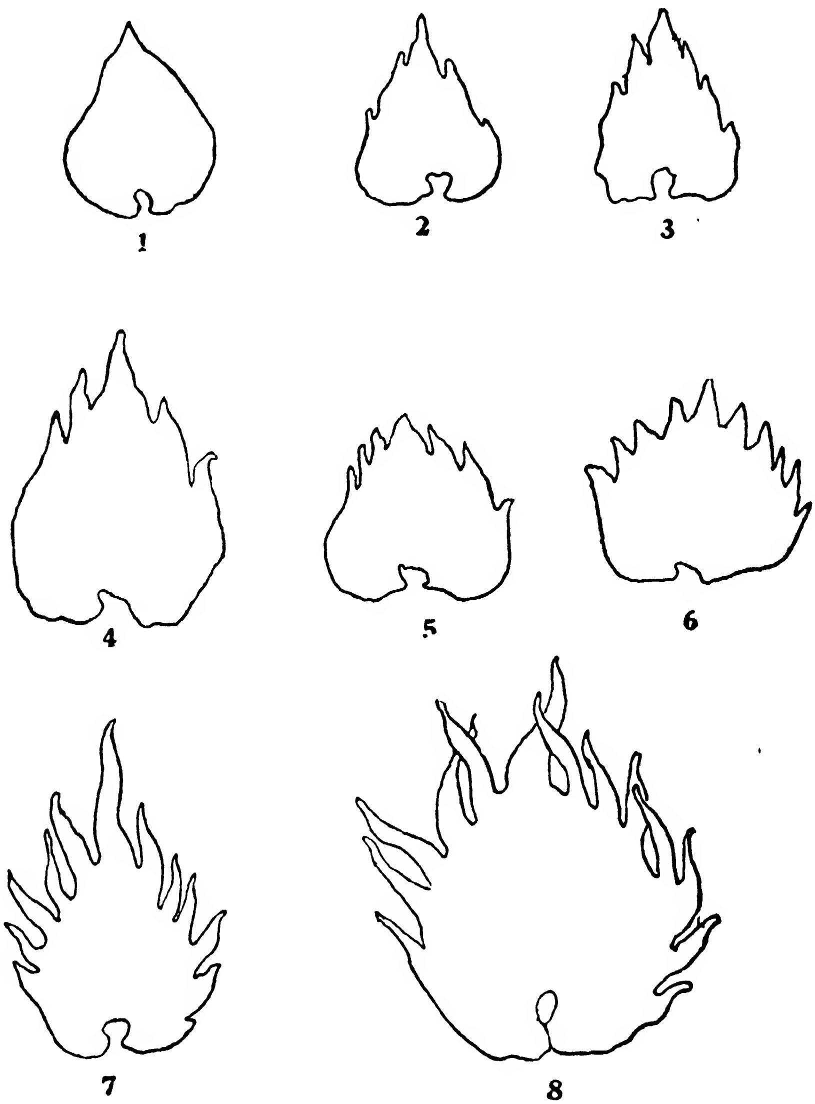
Cotton leaf outlines. (1) G. hirsutum. (2) G. arboreum. (3) and (4) G. herbaceum. (5) G. barbadense. (After Hutchinson and Ghose. Drawn by R. C. Sutradhar).

ing (sympodial) branches. Vegetative or monopodial branches arise from buds at the base of each leaf. These buds are of two kinds : (1) the axillary and (2) extra-axillary buds. The vegetative branches usually develop from the axillary buds, but may also develop from the extra-axillary ones. The fruiting branches develop only from the extra-axillary buds. Sometimes both axillary and extra-axillary buds may develop in the same leaf axil, and therefore both types of branches may arise from the same node. Only fruiting branches bear flowers, whereas vegetative branches do not bear them, but these may give rise to fruiting brances. In most cultivated cottons, fruiting branches do not develop on the lower part of the main stem. It is the vegetative branches which determine the general form of the cotton plant. When there is a considerable development of the lower vegetative branches, the plant acquires a bushy appearance.

The **leaves** of cotton are very variable in shape as well as in size. The leaves are lobed but the number of lobes in a leaf also varies from three to nine. The lobes may be broad, narrow or laciniate. The leaves are arranged about the stem in regular spirals. On the main stem and vegetative branches the arrangement of the leaves, or phyllotaxy, of the Old World cottons is generally 1/3. That is, there are three leaves from one leaf to the next directly above it. The American cottons usually have a 3/8 arrangement. The fruiting branches do not possess this spiral arrangement of leaves. The leaves sometimes possess certain structures which are known as glands or nectaries which secrete certain substances from the plant. These, when they occur, are usually found on the lower surface of the leaf. The presence or absence of these is sometimes a help in the identification of certain strains of cotton.

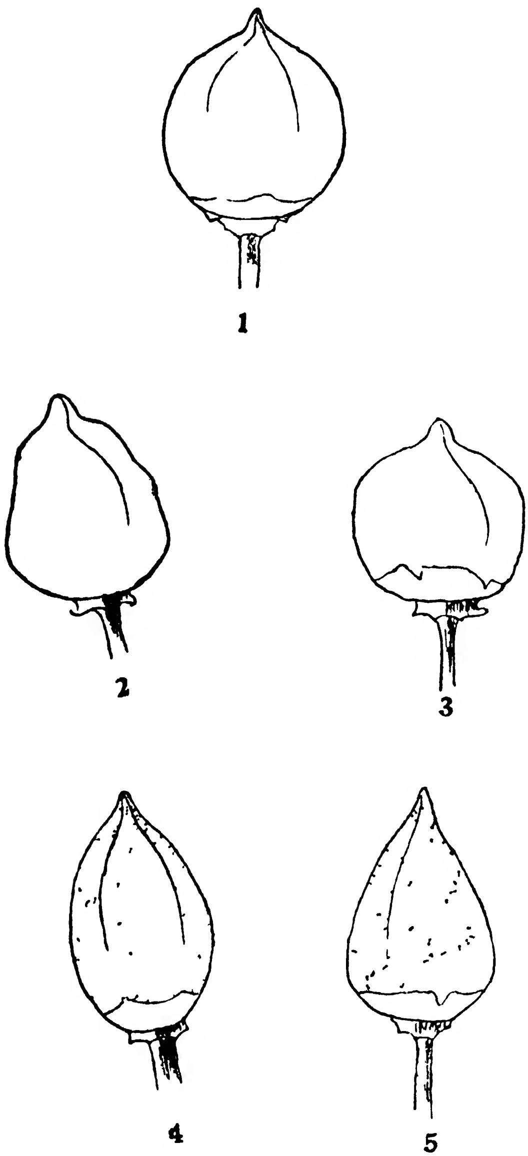
The **inflorescence** of cotton consists of solitary and axillary flowers. The flowers are typical of the *Malvacae* family. The flowers of *Gossypium* are however different from those of the other genera of the family (except *Hibiscus*) in that the anthers in the staminal column are borne below the summit, whereas in the other genera these are borne at the summit. The flowers of the genus *Gossypium* differ from those of *Hibiscus* in that they possess only three bractlets of the involucre whereas the flowers in the latter possess more than three.

The flower is developed at a node opposite to a leaf in fruiting branches only. It consists of the following parts:—(1) The pistil which is formed from several carpels, the number of which may be known from the number of lobes on the summit of the stigma, the carpels later on developing into 'locks' in the boll. (2) The stamens which are very large in number, and are arranged in a tubular form known as the "staminal column" which envelopes the style of the pistil. (3) Five petals which are united at the base, forming together what is



Bracteole outlines. (1), (2), (3) and (4) G. arboreum. (5) and (6) G. herbaceum. (7) G. hirsutum. (8) G. barbadense (After Hutchinson and Ghose. Drawn by R. C. Sutradhar).

known as the corolla. While the colour of the corolla, in most cultivated cottons, is yellow with a red spot at the bottom of each petal, there are numerous variations depending very largely on the variety. (4) Five green sepals joined together forming a cup-like calyx. At the base of the calyx on the inner side floral nectaries usually occur. (5) The involucre which is usually made up of three or four bracts united at the base. These bracts may be large, entire, dentate, or laciniate. At the base of the outer surface of the bracts, nectaries occur in American cottons but are absent in the cultivated Asiatic cottons.



Boll outlines (1) G hirsutum (2) and (3) G herbaceum (4) G barbadense (5) G. arboreum. (After Hutchinson and Ghose. Drawn by R C. Sutradhar).

Normally, cotton is self-fertilized, but natural crossing occurs. When two varieties of cotton are planted side by side in two adjacent rows, natural crossing may take place in from 4 to 20 per cent of the cases but as the distance between two varieties increases, the amount of natural crossing diminishes very rapidly. The fruits of cotton, in which are enclosed the seeds and the fibres, are called "bolls". These also vary in size as well as in shape, but are usually more or less egg-shaped, only smaller and more pointed at the end. Bolls are made up of divisions or locules which are commonly known as "locks". In most cottons, when the

boll ripens, the locules open by separating along their central axis and splitting at the same time along the lines of divisions known as sutures. The number of bolls on a cotton plant varies with the variety, cultural methods and climatic conditions.

The number of seeds in a lock is about nine, so that each boll may contain from twenty-four to fifty seeds.

The cotton fibre is simply an elongation or outgrowth of an epidermal cell of the seed coat. This outgrowth may continue until it reaches a length of an inch or more. These long outgrowths form the "staple" or "lint" which is the cotton fibre of commerce. The shorter outgrowths form what is known as the "fuzz" and is of little commercial importance. Some varieties produce seeds which contain no fuzz and when ginned are practically free from fibres, and are therefore called "naked". The fibre is tubular, but on ripening becomes flat and ribbon-like. On collapsing it forms a spiral band by reason of the unequal collapse and contraction of the cell-wall. The number of twists in the fibre varies with different varieties. In the Indian cottons the average number of twists is about 150 per inch, whereas some of the best cottons may have as many as 300 twists per inch.

The quality of cotton fibres depend upon several characters. The following characters are important in determining quality.

1. The strength of the fibre, that is the actual strain that a fibre can withstand.
2. The number of twists and the character of the twists in the fibre. Fibres with numerous twists, everything being equal, make the strongest yarn.
3. Fineness: This character is mainly due the thickness of the cell-wall. The Indian cottons usually have thick walls and are therefore characterized as coarse, whereas the American cottons usually have thin walls and possess a silky "feel" and are therefore known as "fine" cottons.
4. Uniformity of the fibres: The fibres should be of uniform length, as lack of uniformity in the length of the fibres will result in an undue amount of waste in manufacture.

5. The length of the fibre: Cottons having long fibres are usually preferred to short ones. Indian cottons usually possess short staple lengths.
6. Colour and lustre: Good cottons should possess a rich bright creamy colour.
7. "Counts": This is a term used to evaluate the quality of cotton fibre. A count is the number of hanks required to weigh a pound. A hank contains 840 yards of thread. The finer the thread therefore, the greater will be the "count". Indian cottons ordinarily spin up to about 22 "counts", whereas the best quality cottons may range from about 80 to even 400 "counts".
8. "Neppiness": This is caused by the failure of individual fibres to thicken, resulting in small entanglements of the fibres firmly knotted together and incapable of being unravelled. These entanglements are usually formed during the process of ginning. This is an undesirable character more common in certain varieties of cottons than in others.
9. Ginning percentage: This is the amount of lint obtained in relation to the amount of cotton (*kapas*) fed into the gin. A variety of cotton with higher ginning percentage is preferable, as more lint is obtained per unit weight of seed cotton (*kapas*).

Normally the **root system** of a cotton plant possesses a long tap-root from which the laterals or feeding roots arise. The length of the tap-root may be 3 feet or more. The laterals are only a few inches below the surface of the soil and branch out in all directions. These usually arise from four grooves on the main root, forming four groups of lateral roots.

Ecological factors.—The cotton plant is very sensitive to environmental stimuli, which accounts in part for the various types or forms of cotton under cultivation in India at present.

On the basis of ecological factors, namely soil and climate, the indigenous cottons of India may be broadly divided into two groups:

1. Those that require eight months to mature.
2. Those which reach maturity in five months.

The first group are generally grown in those regions where the growing season is long, that is, where frost does not occur during the whole length of the long growing season required by them. The second group are mainly confined to Central and Northern India where frost generally occurs during the winter.

The cotton plant requires a rather high and uniform temperature during the early stages of its growth, as this encourages vegetative growth. During this period the crop should also have plenty of moisture in the soil whether supplied by rain or irrigation. In the later stages of its growth the temperature should be lower preferably with cool nights. These conditions serve to check vegetative growth and encourage fruiting. If during the fruiting period heavy showers of rain occur, the shedding of the flowers and young bolls may result. This also may be caused by heavy irrigation at this stage.

During the harvesting season it is necessary that the weather should be clear, as showers of rain at this time will discolour the lint and thereby reduce its quality.

In this country the cotton plant is cultivated under a wide range of soil conditions. But the major portion of the crop is grown on the Indo-Gangetic alluvium and the black cotton soils.

Classification of cottons.—The genus *Gossypium* has been one of the most difficult to classify, and therefore a great deal of confusion has resulted. Sir George Watt, the great authority on cotton who was for some time a professor of botany in the Calcutta University, in his monograph published in 1907, described 42 distinct species and varieties of *Gossypium* and divided the wild and cultivated cotton plants of the world into five "sections". More recently the wild and cultivated cottons of the world have been divided into three groups. One group consists of the wild cottons of the New World, with 13 chromosomes. The second group consists of three wild species from islands in the Pacific and the cultivated American cottons with 26 chromosomes. The last group consists of the wild and cultivated cottons of the Old World with 13 chromosomes. Among the cultivated

cottons, four species according to their classification contain the most important varieties. These may be classified as follows :—

New World Cottons: (1) *G. hirsutum* and (2) *G. barbadense.*

Old World Cottons: (1) *G. arboreum* and (2) *G. herbaceum.*

General key for the identification of the most important cultivated species of cotton in India (Adapted from Hutchinson and Ghose's classification).

A. Bracteoles gashed into a varying number of long acuminate teeth closely investing the bud, flower and boll.

B. Habit varying from monopodial to sympodial. Leaf lobes ovate—oblong, usually overlapping at the base causing the sinuses to be thrown up in folds. Corolla not widely expanding, forming a narrow cup. Bolls long, tapering, shiny, dark green, profusely pitted, with oil glands at the base of the pits..........................*Gossypium barbadense.*

BB. Habit sympodial with no or very few vegetative branches. Leaves occasionally palmatisect. Leaf lobes divergent, broadly triangular, not constricted at the base, not overlapping. Corolla widely expanding. Bolls rounded, often large, pale green, surface smooth, oil glands few and sunk beneath the boll surface................ ......*G. hirsutum.*

AA. Bracteoles rounded or broadly triangular, broader than long, with margin divided into a number of triangular teeth, flaring widely from the base of the bud, flower and boll. Bolls rounded, or with prominent shoulders, boll surface smooth, or very shallowly dented, with few or no oil glands ....*G. herbaceum.*

B. Habit sympodial, without or with very few spreading vegetative branches. Petioles, pedicels and leaves hairy or sparsely hairy. Stems almost glabrous below. Leaves large, leathery, usually flat and only slightly constricted at the base of the lobe. Bolls 1" to 1¼" long, not more than 11 seeds per loculus........................ .....Var. *typicum.*

BB. Habit sympodial or monopodial with 0 to 10 ascending vegetative branches. Young shoots woolly. Stems, petioles, pedicels and leaves intensely hairy. Leaves large, thick, rumpled, and only slightly constricted at the base of the lobe. Bolls 1" to 1¼" long, not more than 11 seeds per loculus.. ....Var. *frutescens.*

BBB. Habit monopodial with many ascending vegetative branches. Leaves small, thin, flat, and deeply constricted at the base of the lobe Stems, petioles, pedicels, and leaves almost glabrous. Bolls ¾" long or less, usually 5—7 seeds per loculus.....................Var. *Africanum.*

AAA. Bracteoles triangular, longer than broad, entire or with three or four coarse teeth, closely investing the bud, flower and boll, occasionally spreading away from the apex of the boll. Bolls tapering, profusely pitted, with prominent oil glands in the pits..............*G. arboreum.*

B. Habit monopodial with many vegetative branches, growing into a bushy shrub, bolls 1" to 1$\frac{3}{4}$" long, not more than 11 seeds per loculus.......... ....Var. *typicum*.

BB. Habit sympodial, with few or no vegetative branches, growing into a small shrub, not bushy, 2'—6' high.

C. Bolls 1"—1$\frac{1}{2}$" long, not more than 11 seeds per loculus.........., ...Var. *neglectum*.

CC. Bolls 2" or more long, with 13—17 seeds per loculus.. Var. *cernuum*

Gossypium barbadense.—This group of cottons which is more commonly known as the Sea Island cottons includes most of the long staple cottons of the United States of America and of Egypt. In India these cottons are more commonly known as Egyptian cottons. This group is mainly confined to Sind where it is gaining in popularity. Of this group of cottons two improved strains have been evolved which are now recommended to the cultivators by the department of agriculture in Sind. These are known as "Improved Sind Egyptian Boss III—16", which has been evolved from Zagory Melaky, a variety imported from Egypt, and "Improved Sind Sea Island Cotton 2.4", which has been evolved from a variety originally imported from America. Boss III—16 has a very long staple length of 1$\frac{1}{4}$ inches to 1$\frac{1}{2}$ inches and is very fine and silky. It spins 80's and its ginning percentage is 32 per cent This strain has especially been recommended for East Sind. Sea Island cotton is considered to be the best cotton from the point of view of staple length and fineness. Its staple length is 1$\frac{1}{2}$ to 1$\frac{5}{8}$ inches. It is very fine and silky. It spins 70-80's and gives 30 per cent. ginning outturn. This strain also has been recommended for East Sind.

Gossypium G. hirsutums or American Cotton. (Courtesy of Institute of Plant Industry, Indore.)

Gossypium hirsutum.—This is a group of cottons more commonly known in India as American cottons. It is a group introduced into different parts of India. In the Punjab this group includes two or three well-known strains, Punjab 285F, Punjab 289F and Punjab 4F. More recent reports state that the new varieties of Punjab-American designated 43F and 38F have given better results in

laboratory tests than the earlier ones. In Sind, selections were made from these Punjab strains and some have been found to be better than the imported parents. These are now designated as 4F-98 and 289F-1. In the Bombay Presidency this species of cottons is represented by a group known as Dharwar-American, of which the Gadag strains have been evolved. In Madras the *hirsutums* are commonly known as Cambodia of which one strain, known as Coimbatore No. 2, is among the important ones. In several other parts of India these American cottons are found mixed with the indigenous cottons, such as the *Malan* in Central India, the Mysore-Americans in Mysore and *Buri* in the Central Provinces and Berar.

Gossypium herbaceum.—This species of cotton includes the three varieties *typicum*, *frutescens* and *africanum*. The first is mainly confined to the countries to the north-west of India, and the last occurs chiefly in South Africa. So only one variety of the species *herbaceum* is found indigenous to India. In India this variety *frutescens* is mainly confined to the western coast extending from Cutch to Madras. This species is represented by such groups of cottons as those known locally as *wagad*, *lalio*, *Broach*, *kanvi*, *kumpta* and *uppam*.

The *wagads* are a group of cottons generally grown in the Ahmedabad district in North Gujarat and in parts of Kathiawar and Cutch. These cottons possess a staple length of about $\frac{3}{4}$ to $\frac{7}{8}$ inch, with a ginning percentage of 33. One chief peculiar characteristic of this cotton is that the bolls do not open even when ripe. This group has one particular defect when grown in this area and that is, it is very late in maturing and for that reason is usually subject to frost. Wagad No. 8 has been for some years regarded as an improved type of this group of cottons. The *lalios* and *kanvis* are mixtures of various strains of *G. herbaceum*. These are grown largely in North Gujarat, Kathiawar and some parts of Cutch. The staple lengths of Kanvi are $\frac{1}{2}$ inch to $\frac{5}{8}$ inch, whereas that of *lalio* is $\frac{5}{8}$ inch to $\frac{3}{4}$ inch. These mixtures vary in ginning percentage from 32 to 35. One undesirable characteristic of the *lalio* cottons is that the bolls open at maturity and allow the seed cotton (*kapas*) to fall to the ground.

Broach cottons are grown in the district of Broach and Surat. They usually possess a staple length of $\frac{7}{8}$ to 1 inch. These cottons

have a high value on account of their whiteness and glossiness, and have therefore acquired a high reputation in the cotton trade. Surat 1027 A. L. F. is one of the varieties of Broach cottons recommended to the cultivators Its average staple length is about 1 inch and it spins 34's.

Gossypium herbaceum (Courtesy of Institute of Plant Industry, Indore).

Goghari is a type of Broach cotton and is grown mostly in Gujarat, largely in the districts of Ahmedabad and Khaira. This is a high ginner, with a ginning percentage of about 40. On account of its high ginning percentage it has become popular with the cultivators but due to its short staple its invasion may cause the famous Broach cottons to deteriorate. Measures are therefore being taken to check its spread.

Kumpta cottons are generally grown in the Kumpta, Dharwar Division of the Bombay Presidency, and in the Raichur district of the Hyderabad State. They possess a staple length of $\frac{3}{4}$ to $\frac{7}{8}$ inch, and a ginning percentage of 26. Dharwar No. 1 is a pure type of *Kumpta* cotton and is considered to be an improved type of the tract. Another strain of *Kumpta* cottons which is gaining in popularity in the area is known as Jayawant.

Uppam cottons are generally grown in Coimbatore and Trichinopoly districts of Madras. These cottons possess a staple length of $\frac{3}{4}$ inch and a ginning percentage of 25.

Gossypium arboreum.—This species of cotton is the most widely distributed in India. Three varieties of this species are now being recognized: (1) Var. *typicum* which is a monopodial and perennial type, (2) Var. *neglectum* which is predominantly sympodial and an annual type, and (3) Var. *cernuum* which is also sympodial and annual.

The variety *typicum* occurs mainly in Assam, Bengal, the Gangetic plain and Central India, Peninsular India, Kathiawar and

Gujarat. The types of *typicum* confined largely to the first four regions mentioned are grouped by Hutchinson and Ghose under the designation of *forma bengalensis*, whereas those occurring largely in the last three regions are designated as *forma indica*. *Typicum* is not of very great agricultural importance.

Gossypium arboreum, or the Indian Cotton. (Courtesy of Institute of Plant Industry, Indore).

The variety *neglectum* occurs in India in two forms which are also designated by Hutchinson and Ghose as *forma bengalensis* and *forma indica* respectively. The first form occurs largely in Assam, Bengal, the Gangetic plain, the Punjab, the North-West Frontier Province, Rajputana, Central India, Gujarat, Kathiawar, Khandesh, and parts of the Central Provinces. The second form occurs in the region south of the Tapti river.

The variety *cernuum* is mainly confined to East Bengal and Assam. According to Hutchinson this variety has probably descended from the same parental stock as *neglectum forma bengalensis*. But the *neglectum* has spread from the hilly tracts of Bengal and Assam, almost throughout India within recent times when cheap cotton goods were made in England. This invasion of these coarse-stapled cottons is due to their high ginning percentage.

Gossypium arboreum var. neglectum forma bengalensis is represented in different parts of India by several types, of which the representatives are the following:

1. The *Malvi* cottons which are mainly grown in Central Provinces and Central India represent one of these types. Their staple length is $\frac{3}{4}$ to $\frac{7}{8}$ inch long with a ginning percentage of about 25. Through selection at Indore, considerable improvement has been made both in staple length and ginning percentage. Two important strains have been evolved, Malvi 1 and Malvi 9 the latter with a ginning percentage of 33. This superior strain is therefore being recommended to the cultivators of the area.

2. The *Roseum* cottons in the Central Provinces, Central India and Khandesh in the Bombay Presidency form another type of the *neglectum* cottons. Their staple length is $\frac{1}{2}$ to $\frac{5}{8}$ inch with a ginning percentage of 40. This group has one peculiar characteristic in its favour, and that is that its lint is always cleaner than that of the other varieties of *neglectum* probably due to the way in which the bolls open.

3. The *Verum* cottons represent another group of the variety *neglectum*. They are grown largely in the Central Provinces and Berar. Their staple length is $\frac{5}{8}$ to $\frac{3}{4}$ inch with a ginning percentage of 30. The Agricultural Department of the Central Provinces has put out some strains of verums designated as *Verum* 262 and V—434 and late *Verum* which is now recommended to the cultivators. *Verum* 262 has a staple length of $\frac{7}{8}$ inch. *Verum* cottons as well as the *Malvi* and *Roseum* cottons are grown to some extent in the United Provinces and the Punjab. The three types just mentioned are collectively known as the *Oomra* cottons.

4. The *Mollisoni* cottons are another well-known group in this country. They are mainly grown in the Punjab and parts of the United Provinces. These cottons possess white flowers and somewhat broad leaves. Their staple length is $\frac{3}{8}$ to $\frac{1}{2}$ inch with a ginning percentage of about 40. Mollisoni No. 39 is an improved type recommended by the Punjab Department of Agriculture.

Gossypium arboreum var. neglectum forma indica represents another group of cottons in South India. They probably had a parallel evolution with the *forma bengalensis* cottons of northern India. They are physiologically different from their northern India equivalents, and when grown in northern regions, they develope a bushy monopodial habit similar to that of the perennial type, var. *typicum* from which they probably evolved. They are generally confined to peninsular India, south of the Tapti river. On both sides of the Tapti river the overlapping of these two forms of *neglectum* may occur. This results in the merging of the two forms with a consequent reduction in the distinction between the two forms. The two well-known forms of cotton which represent this group are those usually called the *Karungannis* and the *Banis* of Madras. The southern cottons, while they possess a longer staple length, are

inferior to the northern in ginning percentage. *Karunganni* cottons are now grown mostly in the Tinnevelly area in the Madras Presidency. Their staple length is $\frac{7}{8}$ to 1 inch, with a ginning percentage of about 30. C-7 and A-10 are two improved types of this group of cottons now recommended for Madura, Ramnad and Tinnevelly districts, and C-7 for Coimbatore district also.

Bani represents another group of *arboreum* cottons grown in India. This group is mainly grown in Berar. This is one of the finest indigenous cottons. It has a staple length of about 1 inch and a ginning percentage of about 25. Its lint is strong and glossy. This group of cottons also goes under the trade name of *Oomras.*

Gossypium arboreum var. cernuum is mainly confined to East Bengal and Assam. The variety possesses very long bolls which are about 2 inches or more in length. The staple is very short, $\frac{3}{8}$ to $\frac{1}{2}$ inch, and the lint is very coarse. Its ginning percentage however is high, averaging from 43 to 50. This variety goes under the trade name of Comilla.

CULTURAL METHODS

There are in general two methods of growing cotton in this country, depending upon the two predominant soil types, the black cotton soils and the Indo-Gangetic alluvium.

In the black cotton soil area, which includes the Central Provinces, Central India, the Bombay Presidency excluding North Gujarat, Hyderabad State, Berar, and parts of the Madras Presidency, the usual method is to stir the soil with a local cultivator (*bakhar*) several times during the hot weather. If manure is to be applied this is also done during the hot weather, usually in May. After the first shower or two of the monsoon rains, the soil is thoroughly pulverized usually with a *bakhar.*

In this area cotton is usually sown in lines with a two-coulter drill. The distance between rows usually varies in different parts, commonly from 14 to 22 inches. The distance between rows depends on the type of cotton grown and the fertility of the soil. Sowing is usually done in June, in the northern portion of this area and in August to October, in the Madras area. Before the seed is sown the usual

method is to mix it with mud, or moist cowdung and ashes so as to make the fuzz adhere to the seed-coat. This treatment makes sowing more efficient and by making the fuzz adhere to the seed-coat the seed is brought into closer contact with the moist soil and thereby germination is improved. The amount of seed sown varies from 10 to 20 lbs per acre.

In Madras, cotton is sometimes sown as a mixed crop with horse-gram (*Dolichos biflorus*), Italian millet (*Setaria italica*) and with coriander (*Coriandrum sativum*).

After germination, the plants are generally thinned to 12 to 24 inches apart in the row, the distance between plants being different in different localities. During the thinning operation, "roguing" or the removal of off-type plants is carried on. These off-type plants are generally due to the mixing of seeds at the gin. It is therefore advisable not to sow seeds obtained from the gins if the variety is to be kept pure.

Interculture begins when the plants are about 4 inches high. This is done by a bullock drawn *daura* or hoe, a method which is cheap and effective. A man with a pair of bullocks can cultivate about 4 acres a day. The number of cultivations during the growing period usually varies from two to four. In certain areas in the Bombay Presidency the plough is passed between the rows in September or October as a final cultural operation in order to prevent damage from cracking, a phenomenon which is common with this type of soil.

Picking in northern portions of the Bombay Presidency commences in January and continues until April or May. In the central portions of the province, picking begins in October and ends in December. But in the southern portions, picking begins in March and ends in May. In the Central Provinces picking usually begins in October and continues till December, but under irrigation picking continues till March. In Central India picking takes place in December and January. Further south in the Madras area, cotton is picked from February to July.

In the alluvial soil area cotton is almost exclusively an irrigated crop, and thrives best on loam soil, but does well also on clay loams.

The preparation of a seed bed consists in ploughing with the object of thoroughly pulverizing the soil. Before the seed is sown, planking is done in order to level the land and make the seed bed firm.

The seed is sown either broadcast or in lines. The former is the more common practice. But the practice should be discouraged as it is very inefficient, thus making the cost of production high and also giving low yields.

Cotton is sown in April in most parts of the Punjab except in the south-west where it may be sown up till June. In the United Provinces cotton is sown in May and June with irrigation. In Sind, sowing is done in May.

Where cotton is sown in lines the distance between rows for American varieties is usually about three feet and for local *desi* cottons about two feet. This distance however may be varied according to the soil conditions. On fertile soils the distance may be increased.

In certain areas of the Punjab cotton is grown along with a fodder crop such as *senji* (*Melilotus parviflora*), *shaftal* (*Trifolium resupinatum*) and *berseem* (*Trifolium alexandrinum*).

In the Punjab and the United Provinces, in broadcast sowing, weeding and mulching is done by hand with a *khurpi* but when sown in lines this may be done by a bullock-drawn hoe or cultivator.

The number of waterings given to a crop of cotton in this area varies with the amount and distribution of rain during the season. The first watering is usually given before sowing. If the germination is poor, irrigation may be necessary a week or ten days after sowing. But this should be avoided if possible. If no rain occurs during the growing season water may by applied at three week intervals, each watering to be followed by mulching and weeding. In the Punjab the number of irrigations most commonly given to American cotton is four to six and to *desi* cotton three to five. The picking of cotton in the Punjab begins in October, and continues until the plants are killed by frost. In the United Provinces picking begins in October and continues till December.

DISEASES

The two most important fungous diseases which attack the cotton crop in this country are the cotton wilt in the black cotton soil areas and root-rot in the alluvial soil areas.

Cotton wilt (*Fusarium vasinfectum* Atk.).—The most characteristic symptom of the disease is the gradual drooping and withering of the plants. Either the whole plant or a particular branch may be affected. The drooping generally starts from the bottom upwards, the wilted leaves gradually becoming yellow and then brown. The disease may appear two weeks after sowing, but plants at all stages of their growth may be affected. Wilted plants, however, do not show any external discolouration or markings either on the stem or roots. But when the roots are split open it is found that the woody tissue is blackened in streaks. These discoloured streaks may extend to the small branch roots and also to the stems and branches.

The disease is carried within the seed, but when once established it may continue to live in the soil for several years. Where this disease occurs, it will be noticed that at first a few plants in the field may be attacked, but the circle widens year by year until large blocks of infected soil are formed in which cotton plants are unable to grow to maturity.

The disease may be controlled by sowing seeds from areas known not to have the wilt disease. Where wilt is prevalent only wilt-resistant varieties should be grown. In general it has been found that American varieties of cotton are not very susceptible to the organisms which cause the wilt disease in Indian cottons.

Root rot (*Rhizoctonia* sp.).—This is one of the most serious diseases of cotton in the Punjab, Sind, Gujarat and the United Provinces and is believed to be caused by two organisms—*Rhizoctonia solani* and *Rhizoctonia bataticola*.

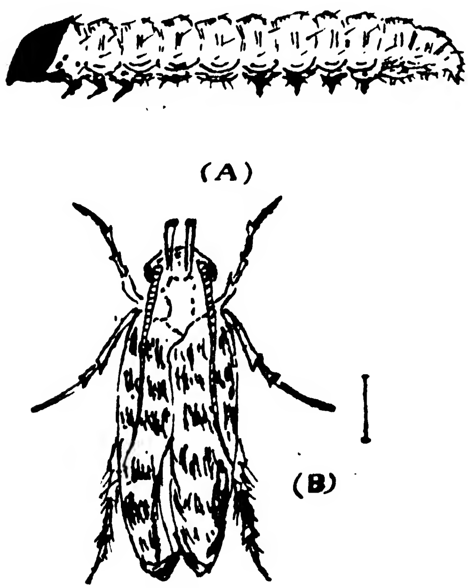
While the disease usually attacks the cotton plants in the seedling stage, mature plants may also be affected. The most important characteristic symptom of this disease is the sudden wilting of the plants. The leaves from top to bottom of such affected plants appear to have suddenly collapsed almost overnight. The disease, however, actually starts much earlier, and therefore the wilting or drooping of the leaves is a late symptom of the disease. Plants affected by this disease can also be uprooted much more easily as almost all the branch roots decay. If the roots of these affected plants are examined it is found that the tip of the root is moist and sticky, and leaves a yellowish stain on a white surface. The bark of the roots of these

affected plants usually breaks down into shreds, whereas the woody portion remains unaffected, except for a slight yellow discolouration on the surface at the early stages of the disease and a brownish or black colour on the woody tissues at later stages.

The fungi which cause this disease live in the soil and therefore any treatment of the disease at present is impracticable. Rotation of crops has been suggested, but the disease is known to live in the soil for several years. As similar organisms cause the root rot of cowpeas and groundnuts, these two crops should not therefore be used in the rotation.

Minor diseases.—Other diseases which are usually less prevalent but nevertheless do some damage to the cotton crop in this country are the following: (1) *Anthracnose*, a disease which is caused by a fungus *Colletotricum* sp. This disease occurs in the Central Provinces and the Madras Presidency. The disease first appears on the bracts as water-soaked circular spots and later spreads to the bolls and causes them to shed. (2) Mildew (*Oidium* sp) which occasionally occurs in the Bombay Presidency. (3) Leaf spot (*Mycosphaerella gossypina*) which occurs occasionally in most parts of India. (4) Rust (*Kuehneola desmium*). This also occurs in most parts of India.

INSECT PESTS.



The pink boll-worm. (A) A full-grown larva. (B) An adult. The Index indicates the original size. Drawn by J. C. Borpujari.

The insects which do the most damage to the cotton crop in this country are the pink boll-worm, the spotted boll-worms, the white fly, the Jassids, the grey weevil, the red cotton bug and the stem borer.

The pink boll-worm.—(*Platyedra gossypiella* Saunders). This insect occurs throughout the plains of India and is a serious pest on cotton in the United Provinces and the Punjab.

This is a reddish caterpillar which feeds in the green or ripe bolls. The caterpillar at the early stages is whitish but possesses a dark head. When young it feeds on the leaves or on the outside of the boll. After a few days it bores through the rind and begins to feed upon the seeds. The mature larva is slender and possesses bright pink spots on its body. When full grown the larva pupates in the boll or on the leaves of cotton. After pupating it emerges as a moth which resembles a clothes moth, and is of a dark brown colour. The moth flies at dusk and also at night and is readily attracted to light. Hence it may be caught in light-traps.

The insect may be controlled by fumigating the seed with carbon bisulphide or by exposing the seed to the hot rays of the sun. A temperature of 140°F. for a few minutes is all that is necessary to prevent any of the caterpillars from becoming moths. Where the damage is serious the first crop of bolls may be picked and destroyed.

The spotted boll-worms.—(*Earias fabia* Stoll and *E. insulana* Boisd). These two boll-worms are almost identical in shape, form and even in the damage they do to the cotton crop. All of the damage done by these insects is during their larval stage. The larva is a short thickish caterpillar about two-thirds of an inch in length. The colour of the body of the caterpillar is usually of a dull greenish white with black and orange spots on the sides. At each segment there are tubercles with hairs. The young larva at first feeds on the leaves and bracts, but later on it enters the boll and feeds on the seeds, eating them one after another. When full-fed it pupates and after some days it emerges as a moth. The moth is dark brown in colour, usually with a broad green band extending from the base to the apex of each wing.

The insects may be controlled by destroying the bolls and the shoots of young cotton plants which contain them. Another method of control is to grow *bhindi* (*Hibiscus esculentus*) as a trap crop. The *bhindi* plants are then uprooted and destroyed.

The cotton white-fly.—(*Bemisia gossypiperda, M. & L.*) This insect was described for the first time in 1929 by Misra and Lamba working at Pusa. But the insect is quite common in the plants in the Punjab where the damage to the crop is reported to be quite serious. The attack of this insect is believed to be more serious on the imported varieties than on *desi* (local) ones. The adult fly is a very small insect

a little over 1 mm. in length (approximately 1/24 inch). The body is yellow and the wings are white. The damage to the crop is done by the larva sucking the juice out of the leaves. The larvae when newly hatched move about for some time and then attach themselves, usually on the lower surface of the leaf. It has been reported that sometimes as many as 250 insects per square inch of leaf were found on the cotton plant. The insect also attacks other crops such as cabbages, *bhindi*, tobacco, mustard, cucurbits and various other crops and weeds.

The insect may be controlled to some extent by practising clean cultivation and the removal of weeds.

Minor insect pests.—Besides the three insects mentioned above there are several others which damage the cotton crop in some parts of India to some extent. But as the damage done is not serious they may only be mentioned here. Those are (1) the Jassids (*Emposce gossypii*) which are believed to be responsible for leaf curl and the "bronzing" of the leaves of certain varieties of cotton, (2) the cotton leaf roller (*Sylepta derogata*), (3) the woolly mites (*Eriophyes gossypii*) which are reported to be serious and widespread in certain parts of the Bombay Presidency, (4) the cotton stem weevil (*Pempheres* sp.), reported to be common in the Madras Presidency, (5) the stem borer bettle (*Sphenoptera gossypii*), which is common in Berar and in the district of Surat in the Bombay Presidency, (6) the red cotton bug (*Dysdercus cingulatus*), (7) thrips (*Heliothrips Sp.*) which are very minute insects, (8) red mites (*Tetranychus bioculatus*), and (9) aphides (*Aphis gossypii*).

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CHAPTER XVI.

JOWAR

Origin and history.—*Jowar* is one of the most important and commonly cultivated crops in this country. Its cultivation in this country has been carried on for several centuries. While the origin of this crop is generally attributed to tropical Africa, it seems very probable that some forms also originated independently in this country. At any rate the greatest variability of this crop is found in Abyssinia, the western parts of tropical Africa, Arabia and India. And while most investigators are of the opinion that the cultivated *jowars* have originated from Johnson grass commonly known in Northern India as *Baru*, or its annual type Sudan grass. Snowden in his recent monograph expressed an opinion that the cultivated *jowars* have arisen from the following four ancestral types: (1) *Sorghum arundinaceum*, (2) *S verticilliflo rum*, (3) *S aethiopicum* and (4) *S Sudanense* According to this author, therefore, Sudan grass (*S. Sudanense*) is partially responsible for some of the cultivated sorghums.

Tops and heads of jowar plants

The cultivation of *jowar* at present is, however, not confined to these regions, but is carried on in China, Australia and the warmer parts of the United States While there are no statistics of the world production of sorghum, undoubtedly India ranks first.

Distribution in India.—In India this crop is being grown in practically all the provinces, but the main areas of production are in the Bombay Presidency, the Madras Presidency, Hyderabad State, the Central Provinces and Berar, and the United Provinces.

TABLE XXXII

Showing the area and production of jowar (grain) in India

Provinces and States.	Area in acres in		Yield in tons in	
	1933-34	1937-38	1933-34	1937 38
Bombay	7,762,000	8,136,000	1,528,000	1,123,000
Madras	4,412,000	4,599,000	1,283,000	1,097,000
Hyderabad	8,834,000	8,480,000	1,161,000	1,308,000
Central Provinces and Berar ..	4,320,000	4,248,000	1,025,000	1,061,000
United Provinces	2,632,000	2,232,000	493,000	436,000
Sind	517,000	439,000	106,000	109,000
Mysore	657,000	656,000	89,000	127,000
Punjab	875,000	838,000	77,000	89,000
Bihar and Orissa	90,000	62,000 38,000	27,000 ..	17,000 12,000
North West Frontier Province ..	86,000	69,000	11,000	8,000
Others	1,982,000	3,167,000	338,000	1,039,000
Total	32,167,000	32,966,000	6,138,000	6,426,000

Botanical description.—*Jowar* is an annual plant which belongs to the great family of grasses known as *Gramineae*, to which the important cereals belong. The plant varies in height with different varieties from 4 feet to 15 feet or more in some tropical forms. In habit and appearance the plant resembles maize (*makka*).

The stems or culms of *jowar* are cylindrical and jointed. The number of nodes is different in different varieties, and consequently the number of leaves and the length of internodes also vary with different varieties. The thickness of stems usually varies, the thicker ones being about one inch in thickness. Most of the *jowars* in this country do not tiller, but some introduced fodder varieties however are capable of producing three or more tillers from one plant.

The stems of *jowar* also vary a great deal with regard to their juice content. Some are quite juicy and sweet, whereas some are pithy

and contain very little juice. Certain introduced fodder varieties are more juicy and also sweeter than the common *jowars* of India.

The number of leaves in *jowar* varies with the number of nodes in the stems but the number is usually from 12 to 20. The leafy character is desirable for fodder varieties. Like the leaves of all grasses, a *jowar* leaf possesses parallel veins and a midrib which is generally white in colour. Some varieties, however, possess a dull-green midrib. It has been found that this character is associated with the juiciness of the stem.

The inflorescence of *jowar* is a panicle with varying degrees of looseness or compactness. Most of the grain *jowars* in India may be classed as compact, loose or intermediate. The broom corns (*Sorghum dochna* var. *technicum*), however, possess very loose and long panicles. The panicles are commonly known as "heads". These vary a great deal in size, shape, form and colour. The peduncle, commonly known as the "neck", may be straight, curved downwards or half-bent. When curved downwards, it is usually known as "goose-necked". The panicle is composed of numerous spikelets which ususlly occur in pairs, one of them being sessile and the other pedicillate. The sessile one is broad, thick and fertile, whereas the pedicillate one is narrow, long and staminate, and hence does not form seed. However, the spikelets occur in threes near the top of the panicle, in which case one is sessile and fertile and the other two are pedicillate and infertile. Occasionally one of the pedicillate spikelets may become perfect.

Within the sessile spikelet two flowers occur, one fertile and the other sterile. Generally one grain is formed as the result of the fertilization of the fertile flower. Occasionally, however, more than one grain may develope, producing a phenomenon known as multiple-seededness. Ayyangar reports as many as six seeds in a single spikelet, but two is the most common. In this country these double-seeded grain *jowars* are known as "*do-dania*". This phenomenon of multiple-seededness has been explained by Karper as being the failure of two or three carpels to fuse into a single pistil and the development of each with an independent ovary containing an ovule. Normally the carpels fuse into a single pistil, each carpel developing a fertile ovule. This development of additional functional flowers within the spikelet is probably responsible for the development of extra kernels.

The *jowar* flowers begin to open after the inflorescence has come out of the terminal leaf sheath which is known as the "boot". The first flowers to open are those near the apex, and blooming proceeds progressively downwards on the panicle. Normally the flowers are pollinated from the higher flowers of the same panicle. But natural crossing also occurs. According to Patel, under conditions prevailing at Surat in the Bombay Presidency, natural cross-fertilization takes place to the extent of 25 per cent. Graham, working in the Central Provinces, estimated the percentage of natural cross-fertilization in a loose panicled type as six per cent, and in a type with a compact panicle 0 6 per cent. One variety gave 20 per cent of crossed flowers. Karper and Conner working in America conclude from their investigations that "in actual field practice where a pure strain is grown near to, and flowering at the same time as another field which might contaminate it, the amount of crossing in the outer rows would undoubtedly not exceed 3 per cent."

Jowar possesses a well-developed root system similar to that of maize but generally wiry and more fibrous, and also usually more abundant. Most of the roots are confined to the upper 1½ feet of soil, but in the later stages of development they may reach a depth of 4½ to 6 feet. The roots are widely and thickly distributed and their absorptive power is so efficient that it is able to exhaust most of the available moisture from the soil.

Ecological factors.—*Jowar* in this country is grown mostly as a *kharif* crop. In Western India and in Madras it is also grown as a *rabi* crop. Its cultivation in this country is mainly confined to those regions where the annual rainfall is not more than 40 inches. In regions with a heavier rainfall the crop is usually replaced by rice. Its water requirement is less than that of maize, and consequently *jowar* is grown as a fodder in regions which may be called semi-arid and where maize will not do well. This peculiar adaptability of *jowar* to dry hot regions is probably due to (1) the high degree of resistance of the plant to injury from dry hot weather, and (2) its ability to stop growing during an unfavourable period for growth, and then to renew growth under favourable conditions without any apparent injury to the crop.

Jowar is generally considered to impoverish the soil. This may be due to (1) the fact that its root system is concentrated on the

upper soil layers to a greater degree than other crops, thus resulting in the exhaustion of the surface soil of its available plant nutrients, and (2) the rendering of available nitrogen unavailable by the action of cellulose-decomposing bacteria during the decay of the sorghum roots and stubble. Whatever the reasons may be, the depressing effect of *jowar* is usually temporary and is most pronounced on the succeeding crop, completely disappearing in a year or two. This depressing effect is least noticeable with legumes and most pronounced with cereals.

Whereas *jowar* is generally grown on all kinds of soil, it does not thrive in sandy soils, and does better on heavier types.

Classification of jowars.—The cultivated sorghums of the world have been classified in various ways by different investigators. Ball, in America, classified the sorghums mainly on the basis of the character and quantity of the juice in the stems and on the character of the panicle, whether loose or compact. In India several attempts were made to classify the *jowars* in the various provinces, such as those by Benson and Subba Rao in Madras, Kottur in the Bombay Presidency and Sabnis in the United Provinces.

Recently Snowden has classified all the cultivated races of sorghum into six sub-series as follows: (1) *Drummondii*, (2) *Guineensia*, (3) *Nervosa*, (4) *Bicoloria*, (5) *Caffra* and (6) *Durra*. According to him the Indian sorghums fall into the sub-series Guineensia, Nervosa, Bicoloria and Durra. *Sorghum Roxburghii* is the only one belonging to the sub-series Guineensia, *S. membranaceum* is the only one belonging to the sub-series Nervosa, *S. dochna*, *S. bicolor* and *S. milliiforme* belong to sub-series *Bicoloria* and *S. durra*, *S. cernuum* and *S. subglabrescens* belong to the sub-series Durra. The value of Snowden's classification for the identification of the cultivated *jowars* of India is rather questionable.

CULTURAL METHODS

The preparation of the land for the sowing of *jowar* is not as thorough as for most of the cereals. In the black cotton soil area, if the land is badly infested with weeds, ploughing followed by harrowing is usually practised. Where ploughing is not necessary,

the land is cultivated with the *bakhar*. In the alluvial soil area the land is usually ploughed two or three times before sowing. In northern India when the monsoon sets in, the seeds are sown either by broadcasting or in rows behind the plough. Sowing in rows is common in the black soil area whereas broadcasting is practised in the Indo-Gangetic alluvium. In the south two crops of *jowar* are usually grown during the year. The "early" crop is sown at the beginning of the south-west monsoon, and the late *jowar* is sown near the end of the south-west monsoon.

When sown in lines the distance between the rows vary from 14 inches to 2 feet, usually depending on the character and fertility of the soil. The plants are usually thinned to a spacing of about 9 to 12 inches in the row. The seed rate varies from 5 to 10 lbs. per acre or an average of about 8 lbs.

Jowar does not usually require any special care after sowing, except an occasional weeding. In the black soil area, weeding is usually done by means of a bullock-drawn hoe known as a *daura*. In the Indo-Gangetic alluvium weeding is usually done by hand by means of a *khurpi*.

When *Jowar* is grown exclusively for fodder purposes the seeds are usually broadcast. The amount of seed sown per acre is also greater, ranging from about 25 to 30lbs. per acre. In fodder *jowar*, no thinning or weeding is ordinarily done.

When grown for grain, the crop is left in the field until the grains are fully mature. The stalks are then cut as close to the ground as possible by means of sickles. They are then tied in bundles and brought to a threshing floor where the heads are cut off and the stalks are stacked. When the heads are thoroughly dry, they are heaped on a threshing floor and the bullocks are made to tread out the grain. The grain is finally separated from the chaff by winnowing. The stalks are usually cut into small pieces collectively known as *kadbi*, which is used for feeding to cattle.

The fodder *jowar* is usually cut when the plants are still green, preferably when the grains are in the "dough" stage. This is cut up almost immediately by means of a handchopper known as a *gandasa*. After cutting, the green *kadbi* is fed to cattle. This method of feeding green fodder to cattle is known as "soiling". Such

a crop is therefore known as a "soiling crop". On the other hand if the green fodder is put into an air-tight chamber or pit and allowed to ferment, the fermented material is known as silage. Such chambers or pits are known as silos. These may be constructed above or below ground level.

DISEASES AND INSECT PESTS.

Red leaf spot (*Collelotrichum graminicolum*).—This is probably one of the most common diseases of *jowar* in India. The disease causes small red spots which are visible on both the upper and lower surfaces of the leaf. When the spot has fully developed, the central area is usually lighter in colour. In this central area one or more black dots may be seen on both sides of the leaf. The disease, while common, does not seem to do much damage to the crop. So far as is known, no control measures for this disease have been worked out.

Rust (*Puccinia purpurea*).—This disease is fairly common in *jowar*, but the extent of its damage has so far been imperfectly estimated. The disease appears on the leaf as bright purplish spots, the purple colour being more intense near the edges. At first the disease is inside the epidermis which later bursts and exposes a light-brown powder which is composed of the spores of the fungus.

Although the disease is found in all parts of India its occurrence in epidemic form varies in different localities and with the atmospheric conditions of the weather.

Minor diseases.—The *jowar* plant is also subject to the attacks of a number of diseases which are of minor economic importance. Some of the common ones are (1) a leaf spot disease caused by *Cercospora sorghi*, (2) downy mildew (*Sclerospora graminicola*), a disease which is more common in *bajra* than in *jowar*, (3) grain smut, perhaps the commonest smut of *jowar* in India and caused by *Sphaceolotheca Sorghi*, (4) head smut, caused by *Ustilago Reliana*, (5) loose smut, caused by *Spacelotheca cruenta*, (6) long smut caused by *Tolyposporium filiferum*, and (7) blight and hollow-stem caused by *Macrophonima phascoli*.

Insect pests.—The insect enemies of *jowar* are not as numerous as those of sugar cane. But certain insects which attack the sugar

cane crop also attack the *jowar* crop. Thus the stem borers which were described under sugar cane may also be found attacking the *jowar* plants. Therefore the methods of controlling stem-borers in sugar cane fields may be adopted for the control of these when they occur in the *jowar* fields.

Other insects of minor importance which attack *jowar* are the blister beetles which feed upon the flowers. These are usually known in three forms. (1) the orange-banded blister beetle (*Mylabris pustulata*), (2) the green blister beetle (*Cantharis tenuicollis*) and (3) the brown blister beetle (*Cantharis rouxi*).

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CHAPTER XVII

TOBACCO

Origin and history.—Tobacco belongs to that family of plants known as *Solanaceae* to which some of our important food crops such as the potato, tomato and chillies belong. Tobacco belongs to the genus *Nicotiana*, but only two species, *Nicotiana tabacum* and *N. rustica*, are used for the manufacture of the tobacco of commerce.

The genus *Nicotiana* is believed to have originated in America. About fifty or more species are contained in the genus, of which the species *tabacum* above mentioned is the chief source of the tobacco of commerce. *N. rustica*, a species which is chiefly grown in Bengal, is another source. The introduction of tobacco into India was made by the Portuguese more than 300 years ago. Its cultivation extended rapidly, and at present the total acreage under this crop is about a million and quarter acres, with a total production of over a thousand million pounds. India is now the second largest tobacco-growing country in the world. Most of this is consumed locally in India in the form of "*biri*", cigarettes, "*hookah*" or pipe tobacco, or as cheroots. Cigarettes, however, are now replacing the "*hookah*" and a number of factories have been established to supply the growing demand. The present policy in India is to develop the cultivation and treatment of tobacco so that India may to some extent take the place of the United States in the supply of tobacco to England.

Distribution in India.—Tobacco is grown in all the provinces of India, but the greatest centres of production are in the Rangpur district of Bengal and the Guntur district in Madras. It is also, to a considerable extent, grown in the Muzzafarpur, Purnea and Darbhanga districts of Bihar; in the Jalpaiguri, Chittagong, Dacca, Jessore and Hooghly districts of Bengal; in the Mainpuri, Etah, and Farrukhabad districts of the United Provinces; in the Jullunder district in the Punjab; in the Peshawar district in the North-West Frontier Province; in the Kaira and Belgaum districts of the Bombay Presidency; and in the Coimbatore and Vizagapatam areas and also the Godavari delta of the Madras Presidency; and in the Goalpara district in Assam. The following table gives the area and yield of tobacco in the different provinces and States in India.

TABLE XXXIII

Showing the distribution of tobacco in India

Provinces and States	Area in acres in 1933—34	Area in acres in 1937—38	Yield in tons in 1933—34	Yield in tons in 1937—38
Madras	248,000	294,000	129,000	125,000
Bengal	286,000	313,000	123,000	130,000
Bombay	140,000	170,000	106,000	44,000
Bihar	140,000	125,000	53,000	52,000
United Provinces	81,000	88,000	50,000	63,000
Punjab	49,000	71,000	20,000	29,000
Hyderabad	73,000	63,000	15,000	17,000
Assam	14,000	12,000	5,000	6,000
Baroda	44,000	53,000	5,000	9,000
Central Provinces	13,000	12,000	4,000	4,000
Mysore	25,000	24,000	4,000	3,000
Sind	4,000	5,000	1,000	2,000
Others	110,000	58,000	46,000	27,000
Total ..	1,227,000	1,288,000	561,000	511,000

Botanical description.—The tobacco plant is a herbaceous annual. *N. rustica* is sometimes reported to behave as a perennial. The tabacco plant grows generally from 3 to 5 feet high. The stems are more or less round, and sometimes produce branches near the base which are known as "suckers." The length of the internodes also varies in different types. Shaw and Kashi Ram recognize three types of internodes as short (below 2 cms.) medium (2-5 cms.) and long (more than 5 cms).

The leaves vary a great deal in number, shape and texture. Tobacco leaves may or may not possess leaf stalks (petioles). The plants of *N. tabacum* may or may not possess petioles, but those of *N. rustica* are petioled. The number of the leaves varies greatly. If the leaves are few, the plant has an open appearance, whereas if the leaves are numerous the plants have a bushy appearance. The shape of the leaves may be elliptical, lanceolate or ovate. The leaves in

N. tabacum may sometimes be 3 to 4 feet in length. The texture of the leaves also varies in different types. In general the texture of the leaves of *N. tabacum* is finer than that of *N. rustica*, which is more or less leathery and tough. The leaves vary in the angles which they make with the stems. In some cases the leaves occupy a very upright position, the angle of insertion being small, while in others the leaves may be practically horizontal or they may bend at various points, *i e.*, at the base, in the centre or at the tip.

The inflorescence of the tobacco plant is a terminal panicle. It may occur very close to the upper leaves or it may be much raised above them. The flowers are usually about 2 inches in length and are either pink, yellow, purplish or white. Those of *N. tabacum* are usually pinkish, whereas those of *N. rustica* are white or yellow. The pink colour in the flowers of *N. tabacum* may sometimes fade, leaving them white. The length of the flowers in *N. rustica* is more or less constant, whereas in *N. tabacum* it is quite variable. The width of the flowers of *N. rustica* varies from about 10 to 15 mms. at the maximum width of the calyx.

In tobacco plants, self-fertilization is common but cross-fertilization does occur, especially when the plants are grown in close proximity. The amount of natural cross-fertilization under field conditions in this country has not as yet been determined. Howard is of the opinion that, since the stamens are arranged in close proximity to the stigma in the flowers of *N. rustica*, probably less natural cross-fertilization takes place in this species.

The root system of a tobacco plant is quite extensive and fibrous.

Ecological factors—Although tobacco is grown all over India, the crop does best where the structure of the soil is sufficiently open for rapid root-development. The tobacco soils are therefore usually those considered as light soils. Usually rich soils, that is those containing plenty of organic matter and nitrogen are not considered the best type of soils for cigarette tobaccos, for the smoke produced by tobaccos grown in such soils is usually objectionable, although the yields may be heavy. However heavier grades of tobacco are grown in relatively fertile soils. A tobacco soil is therefore one that is relatively poor in humus contents, but contains a good amount of potash, phosphoric acid and iron. Tobacco also will not do well in water-logged soils,

due probably to the deficiency of aeration or the development of harmful fungi and bacteria under such conditions.

Of the two species of tobacco, *N. rustica*, under cultivation, requires a shorter growing period It is therefore more commonly grown in the drier, colder regions of north-west India and also in East Bengal where the growth is shortened by floods coming towards the end of the rainy season. The other species, *N. tabacum* is grown largely in Bihar and parts of Bengal and also in Madras and Bombay.

Classification of the Indian tobaccos.—Indian tobacco as mentioned above consists of two species, namely *N. tabacum* and *N. rustica*. The distinguishing characteristics of these two species may be stated as follows :—

N. tabacum.—Leaves sessile or petiolate, in the latter case the petiole invariably winged. Flower pinkish. Grown practically all over India and supplies the major portion of the tobacco of commerce.

N. rustica.—Leaves petiolate. Flowers yellow or white. Widely cultivated in Bengal and the northern parts of the country almost entirely for *hookah* tobacco.

The species *N. tabacum* has been classified by Prof. Comes of Naples (Italy) into six varieties. But his classification has been severely criticised by Anastasia, who reduced the number of varieties to four. In India, Howard and Howard have classified *N. rustica* into 20 different types and *N. tabacum* into 31 types. More recently Shaw and Kashi Ram have further added 18 types to those of Howard and Howard.

CULTURAL METHODS

Seed bed preparation.—Tobacco seeds on account of their very small size are not usually planted directly in the fields, but are sown in seed beds. The seed beds should be located on high well-drained soil. These seed beds should be thoroughly ploughed and cultivated for several months before the seeds are sown, in order to remove all the weed seed that might germinate with the tobacco seeds. The beds should be highly manured, preferably with oilseed cakes or rich leaf mould which should be well mixed with the soil. The land is then made into small raised beds which should be about 4 to 5 feet wide and

separated by drains about 1½ to 2 feet wide and 4 to 6 inches deep. These narrow beds allow work to be done from the sides, and thereby tramping is avoided. The drains between the beds serve both for drainage and as foot-paths. The seed beds are made slightly sloping from the centre towards the drains, in order to drain off the rain water.

The seed is mixed with fine sand or wood ashes and evenly broadcast on the seed beds. This mixing of the seed with sand or wood ashes ensures an even distribution over the whole area. After sowing, the seeds should be pressed in with a light roller. This compacting of the surface soil serves to bring the seeds into closer contact with the soil moisture, resulting in better and more uniform germination. It should be remembered that an ideal seed bed is one that is moist but not wet. The amount of seed necessary for sowing an acre is only $\frac{1}{5}$ of an ounce. That is, one ounce of seed is all that is necessary for planting 5 acres of tobacco. In order to protect the young seedlings at their early stages from heavy rains or from intense sunlight a *chupper* (thatched roof) supported on bamboos is generally constructed. The *chupper* later on is removed during the day, as otherwise the seedlings may become weak or suffer from a disease which generally attacks the plants at this stage and which is known as "damping off". If the seedlings are too crowded, they should be thinned in order to get stocky plants for transplanting. In case weeds appear, they should also be removed. Occasionally the beds should be mulched or cultivated by means of a sharp-pointed peg.

Transplanting.—The field where the seedlings are to be transplanted should be thoroughly ploughed, cleaned and made free from weeds. Several ploughings may be necessary in order to break down the soil to a very fine tilth. When the seedlings possess four to five leaves, they are ready for transplanting into the field. The transplanting of seedlings should be done with care. The root system should not be damaged more than is necessary, and the seedlings should not be exposed to the sun after removal from the seed bed and before planting. In order not to injure the roots too severely, the seed beds are generally watered 8 to 12 hours before the seedlings are to be removed. The seedlings should be removed by levering up with a flat-pointed stick or *khurpi* (trowel). In this way some soil will remain adhering to the roots. The seedlings are then laid on moist gunny

bags or in shallow baskets. The gunny bags or the baskets are sprinkled from time to time with water in order to keep them moist until they are taken to the fields for planting The seedlings are planted in the fields two feet apart in lines which are three feet apart. The transplanted seedlings should be watered immediately. When transplanting, care should be taken not to cover the growing shoot with soil, which may prevent its growth. The seedlings should be watered again the next morning. After transplanting gaps usually occur which are caused by plants dying from various causes. These gaps should be refilled as soon as possible in order to ensure a good and uniform "stand".

Care after transplanting.—About a week after transplanting, shallow cultivation should be given This operation will help to kill the weeds which may have started and will also pulverize the soil. A fortnight later, another shallow cultivation should be given. Subsequent cultivation, if required should be somewhat deeper. In Bihar this latter operation is sometimes done by means of a spring-tooth cultivator which does the work very effectively.

For tobacco leaf of better quality "topping" is necessary. This operation consists in the removal of the terminal bud which produces the inflorescence. This is done by nipping the inflorescence between the thumb and the forefinger without causing too much injury to the plant.

By this operation nourishment which would otherwise have been used up by the inflorescence is directed to the leaves. For coarser tobacco this operation is generally done when 8 to 10 leaves have been formed; but for finer quality tobacco, the plants are topped when 14 to 18 leaves have been formed.

About a week after topping, branches known as "suckers" develope in the axils of the leaves. It is important that these should be removed before they exceed 2 inches in length, as otherwise much nourishment will be taken up by them which should go to the leaves. Usually two or three suckerings are required before the plants ripen. This operation is also done by "pinching off" as in topping.

In carrying out these various field operations great care should be taken not to injure or damage in any way the leaves that are left on the plant, as the injured leaves produce a low quality tobacco leaf.

Harvesting.—The ripening of tobacco plants usually begins six to eight weeks after topping, the length of the period varying with the season and local conditions. When the plants begin to ripen the leaves become yellow and somewhat mottled, droop slightly and become gummy and stiffer. The leaves should be picked when they are fully mature. Picking should begin with the lower three or four leaves at the base of the plant. These are usually the first to ripen and are known as "primings". These are cured and usually sold as lower grade tobacco. Ripening proceeds gradually upwards. It is therefore advisable to have two or three pickings from one field, the first picking consisting of the removal of the lower leaves, and the last picking being of those of the topmost leaves on the plant.

Curing.—The curing of tobacco consists in withdrawing the moisture from the leaf in such a way as to leave the proper colour and aroma in the dried leaf. In this country three methods are now generally followed in order to accomplish this. They are known as ground-curing, rack-curing and flue-curing methods.

The ground-curing consists of simply drying the tobacco on the ground. The leaves are spread on the ground every morning and collected in heaps every evening. This is a very primitive method and is unsuitable for the production of good quality tobacco.

Rack-curing consists of hanging the leaves on bamboo frames covered with a grass roof. This process takes at least six weeks for curing, and is unsatisfactory for the production of a high quality cigarette tobacco.

Flue-curing is the most satisfactory method for the production of a high quality cigarette tobacco. This method consists of hanging the tobacco leaves on racks in a barn under controlled conditions of temperature, air and moisture.

DISEASES

Mosaic.—This disease is caused by a virus which, as has been mentioned before in connection with sugar cane, is an ultra-microscopic body. The disease is highly infectious, and produces mottling on the leaves, that is, certain light-coloured patches appear on the leaves alternately with dark green areas, with a more or less sharp line of demarca-

tion between the two. The disease also causes crumpling of the leaves. The substance causing the disease is present in the sap of a diseased plant; and if this sap is transferred to a healthy plant the latter becomes infected. Persons working in a tobacco field coming in contact with diseased plants may transfer the disease to the healthy plants by merely touching them. The sap carried from a diseased plant on the point of a needle is sufficient to cause the disease if brought in contact with the healthy plant. Even insects going from one plant to another can transfer this disease from plant to plant.

The best method of control of this disease is to pull out all infected plants as soon as the disease is detected Persons handling diseased plants should not touch the healthy ones. Another important method of controlling the spread of the disease in the field is the thorough washing of labourers' hands with a disinfectant at regular intervals.

Wilt (*Bacillus solonacearum*, Smith).—This disease occurs annually in the Rangpur district of Bengal, where it is known by the local name of "*rasa*". The symptoms resemble those of other wilt diseases, the plant undergoing progressive withering and wilting. Stems and midribs of the leaves of infected plants have dark brown streaks. The stems and main roots become discoloured and partly rotted near the ground. When the stems are split open a dark brown discolouration is noticed which extends from the surface into the pith. The infection is believed to take place through injury caused either mechanically through the process of transplanting or cultvation or by means of insects such as Nematodes which bore into the roots or collar of the plant.

So far as is known no control measures can be adopted, and no varieties resistant to this disease have been evolved.

Other diseases known to occur in tobacco in India are the leaf spot (*Cercospora Nicotianæ* Ell. and Ever.) and the mildew (*Erysiphe Cichoracearum* D. C.)

INSECT PESTS

Tobacco stem borer.—(*Gnorimoschema heliopa* Low).—This is one of the most serious insect pests of tobacco. The adult is a small brown moth with narrow wings which are fringed, and is very

similar in appearance to many small moths which commonly occur in fields in this country. But the damage is done by the larva of this moth which is a small whitish caterpillar about one-third of an inch in length. The caterpillar tunnels into the main stem, causing a gall-like swelling where it pupates. No control measure for this insect has been developed.

Tobacco caterpillar (*Prodenia littoralis* Boisd).—This is another very common insect of tobacco. But whereas the stem borer attacks the tobacco stems, this caterpillar feeds on the leaves, and can also eat into the soft juicy stems. This caterpillar is also a serious pest of many other crop plants such as cabbage, potatoes, groundnuts, sweet potatoes and lucerne. The caterpillar when full grown is about 1·4 inches long, and is dark brown in colour. In pupates in the soil, in which it burrows and then forms a compact earthen case around its body.

The insect may be controlled by the application of arsenical sprays, but these should be applied only during the earlier stages of growth, as otherwise some of the poison may be left adhering to the leaves. The moth is not specially attracted to light, so light traps cannot be used to control this insect.

Other insect pests of minor importance which commonly attack the tobacco crop in this country are the green caterpillar (*Chloridea assulta* Guen.) and crickets (*Brachytrypes achatinus* Stoll).

The tobacco plant is sometimes attacked by **a parasitic weed** known as broom-rape (*Orobanche* sp.). This plant is almost all flowers and possesses no leaves. So it gets nearly all its nutrition from the tobacco or any other plant on which it is a parasite.

The parasite may be controlled to some extent by not permitting it to flower and produce seeds. Where the fields are badly infested with this weed, a long rotation which does not contain any host plant for it should be adopted.

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CHAPTER XVIII

POTATOES

Origin and history.—The potato is one of the most important food crops of the world. Its growth in this country, however, is limited, although it is one of the most common of our vegetable crops. The plant belongs to the same family as tobacco, and is of the same genus as the brinjal or egg-plant.

The potato is believed to have originated in the higher regions of the western coast of South America, namely in the table land of Peru and Bolivia, and in the islands of the western coast of Chile. The plant was introduced into Europe very soon after the discovery of America.

The first mention of it in connection with India, according to Watt, is in the account of a banquet at Ajmer given to Sir Thomas Roe in 1615. It appears therefore that potato cultivation began in India not very long after the discovery of America.

Distribution in India.—Potato in this country is mostly grown in the hilly regions, although it is also cultivated in the plains within access of the great markets of large cities and towns. In the United Provinces, the great centres of potato cultivation are Naini Tal, Almora, Mussoorie, in the plains in Farrukhabad and the vicinities of large cities such as Lucknow, Cawnpore and Allahabad. In Bengal, the potato is largely grown near Darjeeling, and in the districts of Jalpaiguri, Rangpur, Hugli and Burdwan. In the Punjab the centres of potato cultivation are the Kullu and Kangra valleys and the Simla hills. In the Bombay Presidency, the main crop of potato is grown in the Poona district. In Assam most of the potato crop is grown in the Khasi and Jaintia hills. In the South, the crop is mainly grown in the Nilgiri hills in the Madras Presidency.

Botanical description.—The potato plant is a herbaceous annual. It may stand erect or become procumbent or even prostrate. The aerial stems are round or angular, pubescent or glabrous, green or purplish, the anthocyanin pigment in the stem being usually present when the tuber is coloured. The swollen underground stems

are known as "tubers". These, it should be remembered, are morphologically stems and not roots, since in common with all stems of other plants, these tubers possess "eyes" which are buds from which stems are developed.

Potato leaves are pinnately compound with more or less petioled leaflets. The shape, size aud spacing of the leaflets are all different in different varieties.

The inflorescence of the potato plant is borne on a primary axis which usually divides into two secondary axes. Occasionally the two axes divide again resulting in a compact racemose type of inflorescence.

The flowers are more or less regular and are perfect. They vary in colour from purplish to almost white, depending on the variety. Most varieties of potato bear infertile pollen, so fruits or berries do not generally form. Potato flowers also produce no nectar and are therefore rarely visited by insects. Hence self-fertilization is natural to the species.

The roots of potato are small and fibrous, and extend downwards to a depth of about 3 to 4 feet and spread horizontally about 2 feet or more from the plant Most of the root system is near the surface.

Ecological factors.—The potato is essentially a cool climate crop. In this country the crop is grown in the summer in or near the hills where the temperature is low. In the plains it is grown during the cooler part of the year.

The best types of soil for the growing of potatoes are loams, and peaty soils. But the soils should be well-drained and not alkaline in reaction. Slightly acid soils are preferable for potato cultivation, especially in areas where a disease known as "scab" is prevalent. Heavy soils are unfavourable for the development and growth of tubers.

Classification—In other countries many schemes of classification of the potato varieties have been devised, but none of these can be of any use to India. The number of varieties of potato grown in this country is not very large, and no scheme of classification of these varieties has been devised. In the plains of India the most common varieties grown are: (1) *Gola*, a round and medium-sized, rough-skinned and brownish potato, the seed of which variety is obtainable from

Dehra Dun and Quetta, (2) *Phulwa*, a whitish potato which produces light purple flowers in large numbers, and is grown extensively in the Farrukhabad district in the United Provinces, (3) *Surkha* or Patna, a pink-skinned variety, with good flavour, and consequently a variety that is extensively grown in the plains. In the hills the varieties grown are those imported from Europe, that have been acclimatised in this country. These hill varieties are also grown in the plains as a late crop.

CULTURAL METHODS

Seed bed preparation and planting.—In the plains, the preparation of the soil for the growing of potatoes consists in ploughing the land several times in order to produce a well-pulverized seed bed. The field should be cleaned of all trash and weeds. This preparation of the soil is usually begun six to eight weeks before the sowing operàtion. During this preparation about 50 cartloads per acre of well-decomposed farm yard manure are applied to the soil. The land is then prepared for irrigation before sowing is done. The field is laid out into strips about 6 feet wide, divided by water channels which run from the main channel, on the highest portion of the field, down the slope to the edge of the field. The strip of land about 6 feet wide is then divided into ridges and furrows 18 inches apart, the ridges being perpendicular to these water channels. These channels should be on the upper side of the strip. Another modification of this is to make ridges and furrows 18 inches apart, these furrows starting from the main or secondary water channels and running down the slope to the edge of the field. When this latter method is adopted, one should be careful to see that the slope is not too steep, as otherwise erosion may take place when irrigation water is applied. The seed potatoes are usually put in about three inches deep and six inches apart on the ridges. For early sowing, whole tubers of small size are generally planted, the seed rate varying from 8 to 12 maunds per acre, depending on the size of the tubers. For late potatoes, the tubers which are much larger, are cut into pieces each having two or three "eyes" or buds, and are planted. The cut pieces are not usually sown for early potatoes as the conditions then are such that the cut pieces may rot. The seed rate for cut pieces

is usually 6 to 8 maunds per acre. The seed used for the late sowing of potatoes is generally obtained from the hills. This is necessary because the potatoes of the early harvest in the plains will not germinate, as, normally, matured tubers have a natural resting period or period of dormancy, during which time they will not sprout even when planted under favourable conditions. It is also desirable because better varieties may be grown than will succeed early in the season. The practice of sowing extremely small tubers in this country is sometimes criticised as it is believed to result in the deterioration of the variety. While small seed potatoes obtained from a variety that normally produces large-sized tubers are not likely to produce a great percentage of small tubers, yet the continuous use of small seed potatoes probably has a tendency to cause the variety to deteriorate, as this method is a natural selection for potato plants producing small-sized tubers.

Care after planting.—In the plains, the usual method is to irrigate the crop four or five times during the growing season, the number usually depending on the amount of moisture available in the soil and on the climatic conditions of the locality. The first irrigation is generally given ten to fifteen days after planting, preferably after the sprouts have come out of the soil. Weeding and cultivating usually follow each irrigation.

When the plants are about six to eight inches high the first earthing up is done. This process consists of taking soil from both sides of the ridge and covering up the lower portion of the plants. This may be done in several ways. But the most common method in India is to earth up by means of *pharwas* or *kodalis* (large indigenous hoes). Some progressive farmers sometimes use an ordinary ridging plough or a three-row ridger for this operation. The second earthing up is usually done before the tops have become large enough to be damaged during the operation.

Harvesting.—The best time for harvesting potatoes is when the tubers are fully ripe. This is indicated by the natural yellowing and drying of the leaves. In this country, a potato crop usually takes about four months to reach maturity. Sometimes potatoes are "lifted" or dug before they reach full maturity in order to take advantage of the higher prices in the early part of the season. Such potatoes do not

keep well, and for this reason should be disposed of immediately. Potatoes when left to reach full maturity usually develope a thicker skin (periderm) which is more resistant to injury and which can therefore be kept longer or shipped greater distances. The deposition of certain waxy substances in the periderm (suberization) makes the fully matured tubers more resistant to drying conditions during storage.

Storage.—Potatoes meant for seed purposes must always be kept for some time before sowing. Sometimes it also becomes necessary to store potatoes which are meant for sale in the market, before they are sold. During this process of storage, there usually results a considerable loss both in quantity and in quality. In the plains of India, it is difficult to store potatoes for seed purposes. Hence several methods for storing potatoes have been tried in this country, but so far with very little success. One of the methods usually adopted is to store potatoes in coarse dry sand, but this is not always successful as the range of loss may vary from 40 to 90 per cent and at times even more than this. Cinders and charcoal have been substituted for sand without very much success. It appears that the storage of potatoes under low temperatures is perhaps the best known method at present. This method of storing potatoes under low temperatures while fairly common in western countries is not practicable in the plains of India. For the present it seems better that seed potatoes be grown and stored in the hills where the temperatures are usually lower than in the plains. Wherever potatoes are stored it is necessary that the individual tubers be examined at short intervals and that the decaying tubers be removed.

DISEASES AND INSECT PESTS.

Late blight (*Phytophthora infestans*).—This is perhaps the most serious disease which attacks the potato in this country. Its appearance in the plains has been sporadic, although it is believed to be always present in some potato fields on the hills. The first appearance of the disease consists of small brown patches on the leaves. Under favourable conditions the disease spreads very rapidly, covering almost the entire surface of the leaf and may even spread to the stalks, resulting in the collapse of the plants by rotting off. The underside of the infected leaf developes wefts of white, sporulating conidiophores.

The disease becomes most virulent and epidemic in warm humid weather. Rains during the Christmas season followed by foggy weather will produce this disease in an epidemic form in the plains of India if it is present. The underground portions of the plants are also attacked. In fact, usually this is the first portion to be attacked, the above ground portions being attacked only under very favourable conditions. Such infected tubers if cut open show rusty brown markings beneath the skin. The disease is usually carried over in tubers which infect the succeeding crop.

The method of preventing the occurrence of this disease in the plains is not to plant seed from those places on the hills where the disease is prevalent. If seed from such localities is secured for sowing in the plains it is advisable to get them early so as to allow them to pass a portion of the summer in the plains, as the fungus causing the disease is believed to be killed at high temperatures such as occur during the summer in the plains of India.

Where the disease is prevalent the spraying of potato fields with Bordeaux mixture is the most common method of controlling the disease.

The growing of potatoes on the same land year after year where the disease is common is not to be recommended.

Ring disease or bacterial wilt (*Bacillus solanacearum* Smith.) This is probably the most common and wide-spread potato disease in the plains of India. It has also been reported to occur in the hilly regions where potatoes are grown. The disease is caused by the same organism as that which causes the wilt in tobacco. The damage to that crop caused by this organism has already been dealt with in a previous chapter.

The disease causes a sudden wilting of the plant. Usually the lower leaves are the first to collapse. Later on the whole plant collapses as though it had been cut. The tubers are also affected, and when cut they show the characteristic brown ring from which the disease gets the name of ring disease.

In order to control this disease, one should not obtain seed from areas in which it occurs. If the cut pieces are used for sowing, the whole lot should be discarded if they show signs of this disease.

When the disease has occurred in any field it is advisable to use a long rotation from which such related plants as tobacco, tomatoes or brinjal should be eliminated.

Minor diseases.—The potato crop in India is also subject to numerous diseases, which are more or less restricted to certain localities. Their damage to the crop as far as is known at present is not of very great economic importance. Some of these are the following:—

1. Early blight (*Alternaria solani*)—This has been found to occur in the Indo-Gangetic plain and in the Nilgiris in South India. The disease is distinguished from other types of potato disease by the pale brown spots on the leaves, surrounded by concentric narrow darker rings.

2. *Rhizoctonia* sp.—There are numerous forms of this organism, but three are known to occur in India and to attack potatoes. This may cause both root rot and tuber rot. Most of the injury is due to lesions on the underground part of the stem. This disease has been found to occur in the district of Poona in the Bombay Presidency, and in Bihar.

3. Leaf blotch (*Cercospora concors*).—This disease is commonly found in Bengal, Bihar and the Bombay Presidency, and is sometimes mistaken for the leaf blight. The disease at first appears on the leaves as small green roundish spots which later change to yellow and finally to brown.

4. Virus diseases.—Potatoes are also subject to certain diseases for which the causal organisms are unknown, but are believed to be some forms of viruses. The attack of the viruses on the potato plants causes certain characteristic symptoms which are known as mosaic, leaf roll, crinkle, rolled edge, spindle tuber, curly dwarf, etc. Probably the most common of these are the mosaic and the leaf roll. The mosaic diseases in general cause the mottling of the leaves and their wrinkling and ruffling, as well as the dwarfing of the whole plant. Leaf roll is the rolling upwards of the leaves parallel to the

midrib. The leaves also are stiff and erect with tints of pink and yellow.

The common method of combating with diseases of this type is the careful roguing of all diseased plants. Persons handling such diseased plants should be careful not to touch the healthy ones. Such persons should also carefully wash their hands in a disinfectant.

Insect pests.—The most common insect pest attacking the potato crop in this country is the green bug (*Nezara viridula*). The insect occurs all over India, including the hilly regions. The adult is a shield shaped insect about five-eighths of an inch in length, of a uniform light-green colour, with a yellowish portion on the head.

The damage to the potato crop is done by both nymphal and adult bugs, which feed on the host plants by sucking the sap from them. The insect is also known to attack wheat, *bajra*, *jowar*, *ragi*, tomatoes and beans.

No satisfactory control measures for this insect have been developed. The use of pyrethrum dust, or pyrethrum dust mixed with an equal quantity of 2½ per cent nicotine dust, will only act as a deterrent as the adult bug is very extremely difficult to kill.

Where the insect is common clean cultivation and a long rotation from which its common food plants are to be excluded, has been recommended for the control of this insect.

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CHAPTER XIX

LINSEED

Origin and history.—Linseed (*Linum usitatissimum*), more commonly known in western countries as flax, is grown in this country mainly for the oil which the seed contains, whereas in western countries it is grown more especially for the fibre which is obtained from the stem and used in the manufacture of linen goods. The plant belongs to the flax family or *Linaceae.*

According to Vavilov, the small-seeded type of linseed grown for fibre and for seed originated in south-western Asia, in a region of which Afghanistan is the centre. From there it spread northwards to Europe and other parts of Asia and south to India, the northern forms evolving into early races with long unbranched stems, whereas the southern forms are late and much branched.

India for a long time supplied the bulk of the world's need for linseed, but in recent years countries such as Argentina and the United States of America have also grown linseed in large quantities. According to the trade figures of 1933—34, the world's supply of linseed from the five leading linseed producing countries was as follows :—

Argentina	1,414,000 tons.
India	376,000 ,,
U. S. A.	174,000 ,,
Uruguay	72,000 ,,
Poland	44,000 ,,

Distribution in India.—In this country the main regions where this crop is grown are in the central parts of the country, chiefly in Bihar, the Central Provinces, Central India, and parts of the United Provinces. It is also grown extensively in Hyderabad. But in general the crop is grown in all the provinces of India, except in the drier parts of Rajputana, and certain areas in the Madras Presidency. The following table shows the distribution of this crop according to provinces and states.

TABLE XXXIV

Showing the distribution of linseed in India

Provinces and States.	Area in acres in		Yield in tons in	
	1933—34	1937—38	1933—34	1937—38
Bihar	599,000	587,000	93,000	87,000
Central Provinces and Berar ..	979,000	1,213,000	87,000	103,000
United Provinces	240,000	316,000	39,000	52,000
Hyderabad State	399,000	471,000	34,000	41,000
Bengal	126,000	137,000	27,000	27,000
Bombay	115,000	107,000	11,000	9,000
Bhopal State	47,000	65,000	5,000	7,000
Punjab	27,000	30,000	3,000	3,000
Others	729,000	883,000	77,000	128,000
Total ..	3,261,000	3,839,000	376,000	457,000

Botanical description.—Linseed is a herbaceous annual growing to a height of from 1 to 4 feet. The Indian linseed is usually shorter, reaching about 2½ feet in height. But linseed in other countries, as it is generally grown for fibre, is very much taller. The Indian linseed is also branched, as this is the character which is desirable for seed production. The linseed of other countries usually consists of a single main stem with few lateral branches which develop towards the upper part of the stem. According to Howard and Rahman, who have divided the linseeds of India into two main groups, the peninsular or South India types and the alluvium types of Northern India, the former are less branched than the latter.

The leaves of the linseed plant are small, narrow and blunt at the apex. Of the two Indian types, the peninsular type sheds its early leaves.

The inflorescence consists of a terminal panicle which bears numerous flowers. The flowers vary in colour, and are usually either white or blue.

The plant is normally self-pollinated but insects visit the flowers which contain nectar glands, so that natural cross-pollination is not impossible.

The fruit is a capsule which is commonly known as the "seed ball". These capsules are divided into five locules or compartments in which the seeds are borne. The seeds are quite small and flattened, and vary in colour from white to dark brown. The oil content of the seeds is usually about 35 per cent. The seed of the varieties from other countries usually has a lower percentage of oil than the Indian linseed. In India also the oil content of the alluvium type is lower than that of the peninsular type. Some of the Indian linseeds now possess an oil content of about 47 per cent. It is generally believed that the white-seeded once produce more oil than the brown ones.

The root system is usually shallow and abundant. The main tap root is slender and possesses small lateral roots which develope in the first 1 to 1½ feet of soil. Again, the two types of linseed in this country possess different types or root systems. The peninsular type is usually more deep-rooted, and the branching does not occur until the tap root has penetrated to a considerable distance. The alluvium type is shallow-rooted with lateral branches developing at once near the surface of the soil. It has been found that the deep-rooted types of the Peninsula produce larger seeds with a higher oil content than the alluvium types.

Ecological factors.—From the fact that linseed is grown in this country and can be grown also in other parts of the world up to 62° N. latitude, it may be said in general, that the plant can stand different types of climate. However, in this country linseed is grown in many parts of India as a cold season (*rabi*) crop. Some Russian investigators believe that the production of linseed with a high oil content requires much light and warmth and less moisture. When grown for fibre, the best results are believed to be obtained in cool, moist climates. In general it may be said that linseed can be grown successfully wherever wheat is grown.

Linseed can also be grown in almost all types of soil, where sufficient moisture is available, but it will do best on the heavier soils which are more retentive of moisture. The peninsular type is mainly grown in the black cotton soil, to which it is especially adapted due to its deep rooting habit, quick growth and early maturity, which are all desirable characters on account of the cracking of the soil and the consequent rapid loss of moisture. The alluvium type which is shallow-

rooted, slow-growing and late ripening is more adapted to the alluvial soils of the Indo-Gangetic plain where more moisture is usually available. This type is therefore grown in the Indo-Gangetic alluvium of Northern India.

Classification.—The Indian linseeds have been classified by Howard and Abdur Rahman (1922-1924) into 26 varieties which include 123 different types. The main grouping of these different varieties is according to the colour of the seeds, that is whether yellow, (white), fawn coloured or brown. The three divisions are then sub divided according to the colour of the corolla, that is whether white, light blue, blue or purple. The finer sub-divisions are according to the colour of the anthers, then of the filaments, and the style and finally according to the size of the seed, that is whether bold (large), medium or small.

Seed bed preparation and planting.—The land where linseed is to be grown is prepared in almost the same way as wheat lands are prepared. The object in the preparation of the land for sowing is to secure a fine, firm and porous seed bed. This is accomplished by ploughing the land several times, followed by harrowing or the removal of all weeds and trash. The land is then rolled or planked by means of a planker or *patela*. When the land is ready for sowing, the seeds are sown usually by means of a drill or by dropping seeds through a tube attached to a *desi* plough. The seeds are also sometimes sown by broadcasting. In certain localities it is sown as a mixed crop with gram or with *rai* (*Brassica juncea*). When sown alone and in lines the distance between two lines is about a foot. The amount of seed sown in this way varies from about 8 to 12 lbs. per acre.

The crop usually requires no care after sowing, except that when planted late it may require irrigation. No weeding is necessary if the land has been well prepared before the seed is sown. In most parts of India sowing is done in the middle of October, when wheat and other *rabi* crops are sown. The varieties of linseed that have been recommended by the Pusa Research Institute are Types No. 12, No. 121, and No. 124. More recently new hybrids have been produced and several of these appear to be promising.

In Central India several selections have been made, out of which the following have been found to be promising: E. B. 3, with an oil

content of 49·32 per cent. and Dhar white, with an oil content of 47·15 per cent.

In the United Provinces, work with linseed is being carried on and several strains have been evolved which are now under trial in different parts of the province. Of these E. B. 1150 seems to be one of the promising strains for the province.

In the Central Provinces, E. B. 3, a promising variety, has been crossed with certain rust resistant varieties from Pusa and imported varieties of flax. The results of these crosses are now under trial.

Harvesting.—The crop is usually ready for harvesting about the beginning of March. When the crop is ripe it is cut with sickles and then taken to the threshing floor where the seeds are beaten out and winnowed. The seeds are then ready for marketing.

Diseases and pests.—The linseed crop in most parts of this country may be said to be almost free from serious diseases or insect pests. The most injurious of the fungous diseases attacking this crop is probably rust (*Melampsora lini.*) This disease attacks both the leaves and the stems of the plant. The leaves and stems of the affected plants are covered with bright orange coloured pustules, which later may turn brown or black. The disease is probably transmitted through fragments of branches or leaves of the previous crop included amongst incompletely cleaned seed. Direct control measures for the disease are not practicable.

The other disease which is found in linseed but which is less common in this country is known as flax wilt (*Fusarium lini.*) This disease attacks plants at all stages of their growth. The affected plants simply dry up and die. The roots of such affected plants when examined will be found to show a characteristic ashy appearance. The disease is dessiminated through the seed. The disease therefore may be controlled to some extent by seed treatment. This may be done by moistening the seeds in a mixture of a pound of formalin with forty gallons of water. This quantity of the solution is sufficient to treat about 50 maunds of seed.

Another disease which has been reported on the linseed crop is an *alternaria* blight, but it seems that this disease occurs only in some restricted areas in the United Provinces.

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CHAPTER XX.

GRAM.

Origin and history.—Gram (*Cicer arietinum*) is probably one of the most common of the pulses in this country. It is used for human consumption as well as for feeding to animals. This pulse has been known in this country for a long time. Its origin was probably in south-western Asia, that is, in the countries lying to the north-west of India, such as Afghanistan and Persia. According to De Candolle, the fact that gram has a Sanskrit name would indicate that the crop has been under cultivation in this country longer than in any other country.

Distribution in India.—This crop is grown mostly in the Punjab, the United Provinces, Bihar, the Central Provinces and Berar and Hyderabad State, although it is grown to some extent in almost all parts of India. The following table shows the distribution of gram in India and the total yield from each of the provinces and states mentioned.

TABLE XXXV

Showing the distribution of gram in India

Provinces and States.	Area in acres in		Yield in tons in	
	1934-35	1937-38	1934-35	1937-38
United Provinces	5,510,000	5,757,000	1,525,000	1,643,000
Punjab	3,621,000	3,755,000	798,000	640,000
Bihar and Orissa	1,457,000	1,366,000 5,000	495,000	453,000 2,000
Central Provinces and Berar ..	1,236,000	1,191,000	253,000	222,000
Hyderabad State	1,251,000	1,255,000	203,000	198,000
Bombay	764,000	674,000	114,000	95,000
Mysore	885,000	785,000	71,000	85,000
Bengal	207,000	279,000	70,000	72,000
Sindh	259,000	363,000	36,000	61,000
North West Frontier Provinces ..	219,000	142,000	29,000	26,000
Madras	115,000	52,000	20,000	10,000
Delhi	38,000	56,000	11,000	16,000
Others	260,000	42,000	86,000	7,000
Total ..	15,822,000	15,722,000	3,671,000	3,530,000

Botanical description.—This plant belongs to the family of legumes (*Leguminosae*). It is a much-branched annual attaining a height of about 2 feet or more. The plants may be either erect or of a spreading type. A group of grams known as Kabuli grams are generally taller than the local Indian crop, and stand more or less erect. The main branches usually produce not more than one secondary shoot, but in some types the main branches may produce numerous lateral branches.

The leaves are pinnately compound, usually with one terminal leaflet. The number as well as the size of the leaflets, however, varies in different types. The colour of the leaves also varies in the intensity of the green colour, some being light green while others are green or dark green. Certain types also possess leaflets with red margins.

The flowers are papillionaceous, and possess various colours which vary from white or greenish to various shades of pink or blue. The flowers are usually solitary and are developed at a node opposite to the leaf. The pods usually contain two seeds. However, one or three seeds per pod often occur The flowers in gram are normally self-pollinated, but nevertheless natural crossing occurs occasionally.

The seeds vary in size as well as in colour. The seeds of certain types are whitish, while others are either yellowish, brown or reddish. The intensity of colour of the seeds in any one plant may vary, due to an imperfect development of the colour, on account of unfavourable weather conditions during the ripening of the grain.

Gram has a well-developed root system. The roots usually include a central tap root with numerous lateral branches which spread out in all directions.

Ecological factors.—Gram is a cool season crop in this country. Like wheat and linseed, in Northern India it is sown about the middle of October after the rains are over.

Gram is fairly sensitive to the conditions of the weather during flowering time. Frost during this period will result in the failure of the flowers to develop seeds or in the killing of the seeds inside the pod. Heavy showers are also detrimental to this crop, as too much moisture in the soil is not favourable for its development.

The best type of soil for gram is one which is well-drained and not too heavy. Some of the heavier soils which are good for wheat

are not very suitable for gram as high fertility in the soil stimulates excessive vegetative growth at the expense of seed production. Consequently in most parts of the country gram is grown in fairly light soils, mostly loams, which are too poor for wheat.

Classification.—The Indian grams have been classified by the Howards and Khan, and later by Shaw and Khan. The Howards and Khan classified the grams obtained from several parts of the United Provinces and Bihar into 25 different types. Their classification was mainly based on the size of the plants, leaves, flowers and seeds. Further sub-divisions were based on the colour of the corolla, that is whether white, blue, pink, or greenish. Finer sub-divisions were based on the following characters: (1) the presence or absence of hairs on the standard and wings, (2) the dropping off or persistence of the standard, (3) the earliness of maturity, (4) the colour of the seeds, (5) the habit of the plants, that is whether erect or spreading, and (6) the colour of the leaves.

More recently Shaw and Khan made a further study of the Indian grams which were collected from all over India and added 59 types to the 25 types previously classified, thus giving 84 types altogether. According to their classification, type No. 1 is separated out from other types on the basis of the persistent character of the standard. The other 83 types were then further classified on the colour of the flowers, that is whether blue, white or pink. Of these types, type No. 13 is the only one possessing blue flowers. The other characters used for further classification of the types are the size of seeds, colour of grain, shape of grain, character of the seed surface (that is, whether puckered or smooth), the size of pods (that is, whether large, medium or small), earliness, colour of the leaves, number of flowers on the peduncle, etc. References to these classifications are given at the end of this chapter.

Cultural methods.—The land where gram is to be sown usually does not require as good preparation as in the case of wheat. Generally one or two ploughings are given, and ordinarily the seed bed is not pulverized. The crop is usually grown on land which has been left fallow during the *kharif* season, but sometimes it is also grown on the land where an early fodder crop such as *jowar* has been grown in the *kharif* season. This is usually sown earlier than any other *rabi* crop.

The sowing is usually done about the beginning of October in most parts of northern India. The seeds are usually sown by dropping them through a tube attached to a *desi* plough. The amount of seed varies from about 15 seers in the Punjab to 20 in the Central Provinces. Certain varieties of gram such as the *Kabuli* gram have been found to do better with a higher seed-rate. The crop does not require any care after sowing. It is believed by most cultivators that nipping off the tips of the shoots just before flowering encourages more branching and thereby increases the yield. The crop is usually not irrigated. Even heavy rains during the period of its growth may sometimes damage the crop.

When the leaves of the crop begin to turn yellow and the plants begin to dry up, the crop is ready for harvesting. This is done by cutting the plants with a sickle and they are then taken to the threshing floor. The cut plants are allowed to dry for a few days, and are then threshed by having the bullocks tread on them as in the case of wheat. The chaff (*bhusa*) is separated from the grain by winnowing.

Diseases.—The gram crop in this country is subject to the attack of two diseases which are called blight and rust. The former is commonly found in the Northwest Frontier Province and in the Punjab, whereas the latter occurs in the more humid regions of the country, such as Bengal, Bihar, Bombay and Madras.

Blight (*Ascochyta Rabiei* (*Pass*) Lab—*Phyllosticta Rabiei* (Pass) Trot) has been found to cause serious damage to the crop in the Northwest Frontier Province and in the northern Punjab. The disease is caused by a fungus and appears as brown or dark spots on the leaves, stems and pods. The spots vary in size and are usually circular on the lamina and pods, but elongated on the stems and petioles. These spots generally encircle the stem completely, causing the plant to droop and die. The disease is seed-borne, and is also carried on the plant parts which compose the *bhusa*, and in other crop residues. The disease may therefore be controlled by the use of disease-free seeds and the elimination of all crop residues by harvesting the crop by pulling up the plants. The disease may also be controlled by ploughing under all crop residues at the beginning of the monsoon rains, while all debris from the threshing floor should be burnt. The *bhusa* also should not be allowed to get to the fields. Mixed cropping with

wheat or barley is also believed to help in checking the spread of the disease.

Rust (*Uromyces Ciciris-arietini*) in gram occurs in Bengal, Bihar, Madras and Bombay. The disease is caused by a fungus which chiefly attacks the leaves. The disease occurs as small rusty brown pustules on both surfaces of the leaves, but more frequently on their lower surfaces.

No practical method of controlling this disease is now known.

Besides the above two diseases, gram is also subject to wilt. This causes a uniform wilting of the plants. The disease is believed to be due to physiological conditions or to a fungus known as *Rhizoctonia baticola*. Dastur, working in the Central Provinces, believes that more damage is caused to the gram crop by the physiological wilt than that caused by *Rhizoctonia baticola.*

Insect pests.—One of the commonest insect pests which attack the gram crop in this country is known as the gram caterpillar (*Chloridea obsoleta*). The adult of this insect is a moth, but most of the damage is done by the caterpillar. This caterpillar, which is about an inch long, is usually greenish but with tints of various colours. It feeds on the leaves as well as pods, but later on it attacks the seed by biting through the pod. However, it does not go inside the pod but feeds on the seeds from outside it. The insect is known to attack several crops. No control measures for this insect have been devised.

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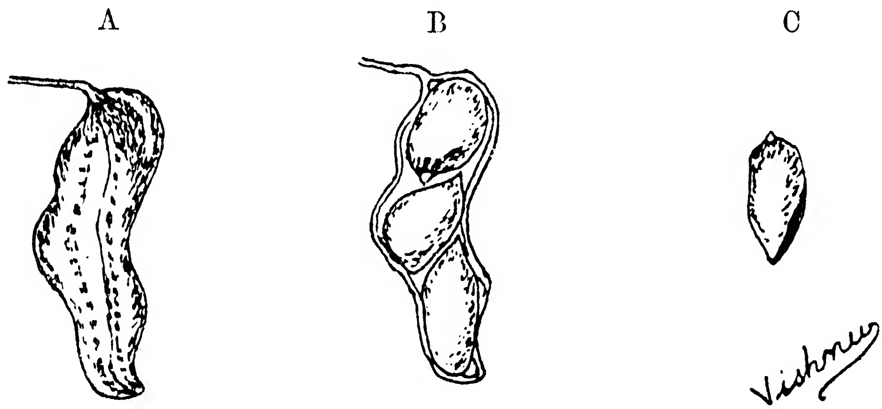
CHAPTER XXI

GROUNDNUTS

Origin and History—The groundnut or peanut is one of the most common oilseed and food crops of this country. Its cultivation and total production is greater in India than in any other country of the world. But the plant has only recently been introduced into this country. Its native home, according to the consensus of opinion of most investigators, is Brazil in South America. It is believed to have been taken into other countries by the Portuguese. It was probably introduced from the Phillipines into South India, whence the name *Manila-kotai* or from China into Bengal where it is known as *Chini-*



A. Unshelled peanut; B. Shelled peanut showing seeds inside; C. A single seed of peanut.

badam, or from Africa or even direct from Brazil into western India. Or it may have been introduced independently from each of these countries. Its cultivation in this country on a field scale, however, seems to have begun about the year 1800, in South India. Since then its cultivation has been spreading very rapidly, especially in the black cotton soil areas where it is being used as a rotation crop for cotton.

The other countries which compete with India in the supply of groundnuts to the world's market are French West Africa, the United States of America and the Dutch East Indies.

The world's production of groundnuts at present is estimated at about 5 million tons a year, of which India contributes about 3 million

tons. About 40 per cent of groundnuts in world trade are from India.

Distribution in India.—Although the crop is now commonly grown in most parts of the country, yet most of the groundnuts are produced in the Presidencies of Madras and Bombay and in Hyderabad State.

During the five years ending 1933-34 the Madras Presidency alone had 48·2 per cent of the total area under groundnuts in India.

The following table shows the distribution of this crop in India according to provinces and states.

TABLE XXXVI

Showing the distribution of groundnuts in India

Provinces and States.	Area in acres in		Yield of unshelled nuts in tons in	
	1934-35	1937-38	1934-35	1937-38
Madras	2,351,000	4,658,000	920,000	2,059,000
Bombay	891,000	1,214,000	389,000	462,000
Hyderabad	962,000	1,438,000	224,000	476,000
Bombay States	654,000	1,022,000	156,000	347,000
Central Provinces and Berar ..	148,000	215,000	38,000	55,000
Mysore	163,000	198,000	27,000	37,000
Others	709,000	..	142,000	..
Total	5,878,000	8,745,000	1,896,000	3,436,000

Botanical Description.—The groundnut (*Arachis hypogaea*) is a member of the pulse family (*Leguminoseae.*) It is a herbaceous annual with a more or less upright central stem, and with numerous branches which may vary from prostrate to almost erect, depending on the variety. The central stem is usually taller in the erect types. The branches may vary in length from about 1½ to 2 feet.

The leaves are pinnately compound and are composed of two pairs of oval leaflets.

The flowers are borne at the axils of the leaves, either above or below the ground. Sometimes when a portion of a branch is covered with soil, flowers may form and bloom, and the fruit may develope without appearing above the soil. It was formerly generally believed that the flowers are of two kinds, fertile and infertile, but it is now generally agreed that they are of one kind and are always perfect. The corolla is orange yellow in colour and is placed at the end of a long slender tube which is the calyx crowned with five calyx tips. After fertilization the ovary stalk elongates, bends over, pushes the minute ovary into the soil where the pod begins to develope, and increases in size. It is very essential that the ovary be able to push itself into the soil, as otherwise fruit formation does not take place.

Ordinarily groundnut flowers are self-pollinated, but cross-fertilization may take place due to the visitation of the flowers by insects.

The fruit is an oblong, more or less constricted pod of pale straw colour, which varies in size according to the variety. The pod contains one to several ovoid seeds. The shell of the pod which contains the seed is morphologically the pericarp and the thin skin which covers the seed or nut is the seed coat or testa. The testa varies in colour in different varieties. It may be brick red, russet or light tan. The nut is composed of two cotyledons. It is these structures which contain the oil and other food materials.

The root system in the groundnut plant is not well developed. It consists mainly of a tap root and a few lateral branches.

Ecological factors.—The groundnut is essentially a tropical plant and therefore requires a long and warm growing season. While the plant requires a certain amount of moisture, an excess of water is detrimental to its growth. In this country it is usually grown in regions where the amount of rainfall is from 20 to 35 inches annually. During its ripening period it is essential that there should be about a month of warn dry weather. It seems that the plant will grow best where the mean temperature is from 70° to 80°F. Lower temperatures are not suitable for its development and frost is very detrimental to this crop.

The type of soils most suitable for this crop are light soils, well manured and rich in organic matter. In this country most of the

groundnut crop is grown in the black cotton soils of the Madras and Bombay Presidencies and the red soils of the Deccan. But the crop also does well in the alluvial soils of the Indo-Gangetic plain.

Classification.—The cultivated groundnuts have usually been divided into two classes, the erect and the trailing types. The erect types were called by Waldron *Arachis hypogaea* sub-species *fastigiata* and the trailing or running types sub-species *procumbens*. He is of the opinion that these two have independent origins, the erect type having originated from *Arachis pusilla* and the trailing type from *Arachis prostrata*. It it reported, however, that the two types have been crossed frequently and hybrids produced which do no show any evidence to indicate that they are species hybrids.

The varieties of groundnut cultivated in India seem to fall into four main groups as follows:—

1. *Mauritius groundnuts*: These are also sometimes known as Mozambique, Pondichery of Coromandel Machine shelled.
2. *Bombay Bold* : These consist mainly of the Big or Large Japan and the American Virginia variety.
3. *The Spanish Groundnut* : These are sometimes known as Natal nuts or Khandesh nuts when they come from that area.
4. *The Small Japan groundnuts*: These are known locally by different name such as Lal Boria, Red Ponani or Red Natal.

A general key to the varieties of groundnuts cultivated in India.

A. Habit trailing or running ; pods produced along branches, some distance from the base ; late maturing........................ subspecies *procumbens*.

B. Branches prostrate, pods medium size; constrictions of pods not pronunced.......................................Mauritius varieties.

BB. Branches spreading laterally but some half erect; pods very large ; constrictions of pods well-pronounced.........Bombay Bold varieties.

AA. Habit erect ; pods clustered near the base ; early maturing.......... .... sub-species *fostigiata*.

B. Constrictions of pods well-pronounced ; seeds small, more or less round, of a light rose colour when fresh, darkening with age ....Khandesh (Spanish) varieties.

BB. Constrictions not so pronounced ; seeds more or less round, blood red or dark red...... ....Small Japan varieties.

Cultural methods.—Groundnuts are generally grown as a *kharif* crop. The land should be thoroughly ploughed. The first ploughing may preferably be done immediately after the *rabi* harvest. In several parts of Madras the crop is also sown during the *rabi* season. In such cases groundnuts may follow groundnuts in which case the number of ploughings will be less for the second crop, since some ploughing would have been done in connection with the harvesting of the previous crop The land should be worked until it is fairly well pulverized

The method of planting groundnuts varies in different regions. In certain areas the seed is drilled, while in some others the seed is dropped in the furrow opened by the plough. The seeds when dropped in the furrow are covered by means of a planker (*pathar* or *patela*) The covering of the seed is very necessary, as otherwise they may be picked up by birds, jackals or other animals. When planted in lines the distance between lines is about one foot, and the distance from plant to plant in the lines varies from 4 to 9 inches. In several parts of Madras, the groundnut is sown mixed with such crops as *bajra* or *cumbu*, sesamum, and *ragi*. In such cases it is sown at the time of the first hoeing of the sown crop by hoeing in the seeds of the groundnuts. The amount of seed sown per acre varies with the locality as well as the variety sown. Mauritius varieties in Madras are usually sown at the rate of 30 to 40 lbs. per acre, whereas the bunch types require about 80 lbs. of seed per acre.

The seeds are generally sown after they have been shelled, but sometimes unshelled pods containing only one seed per pod are selected for sowing. In some cases such one-seeded pods are cracked and sown without removing the shell. It is however always advisable to sow shelled nuts as this allows one to judge their quality better.

In the Madras Presidency the common varieties of groundnut sown are Mauritius, a trailing type, and *Gudiyattam* (Spanish) a bunch type.

In the Bombay Presidency and the Central Provinces the varieties generally grown are Bombay Bold, the Spanish or Khandesh types and small Japan. The Akola varieties of the Central Provinces are gaining in popularity in the province. Of these Akola 10 and Akola 12-24 are the most promising and have been found to do well outside that province.

Apart from yield, further improvement of these varieties should aim at a higher oil content, and the production of a strain in which all the pods should ripen at about the same time.

When groundnuts are sown in lines they are usually cultivated by means of a bullock-drawn hoe (*daura*) until the plants develope the gynophores or "pegs" in which the pods are borne. This stage is indicated by the production of flowers. If a later weeding is necessary, and this should not be done ordinarily, it should be done by pulling the weeds carefully by hand. At this stage there is always a danger of damaging the developing pods in the soil. When groundnuts are sown as a mixed crop, usually all the weeding is done by hand or by hoeing.

In the Madras and Bombay Presidencies the groundnut is to some extent grown as an irrigated crop. In that case furrows are made between the lines and the water is made to run down these furrows.

Groundnuts, being a leguminous crop, usually do not require any manure, but in Madras where they are grown from year to year in the same field, the application of a potash fertilizer may be necessary. Experiments in the Central Provinces seem to show that an application of sulphate of potash is profitable for groundnuts. In some soils an application of lime has also proved beneficial to the crop.

Groundnuts should be harvested when fully ripe. If harvested before this stage there is a high percentage of fatty acid which has not been converted into oil. It has been found that the harvesting of groundnuts even one week before the nuts are fully ripe decreases the oil content by about five per cent.

The maturity of the crop is usually indicated by the yellowing and shedding of the lower leaves. Ripe pods may be distinguished by their darker colour and comparative dryness. However all the pods in the plant do not mature at the same time. Nevertheless the crop is usually hravested at one time.

Harvesting is done in several ways depending on the locality and character of the soil. In the lighter soils the plants are usually pulled up by hand, and practically all the pods come out with the plant. But in heavy soils, such as the black cotton soil, the tops are usually cut off by sickles and the pods are brought to the surface by ploughing. The pods are then usually picked up and dried. The leaves and stalks are usually fed to cattle.

A heavy rain during the harvesting period is usually very detrimental to the crop.

Diseases. — Of the diseases which attack this crop in this country, perhaps only one is of economic importance. This is commonly known as the *tikka* disease, and is caused by a fungus (*Cercospora personata* (B. and C.) Ellis *Septogloeum Arachidis* Rac.). The disease usually appears on the leaves in the form of small dark brown spots. These spots increase in size and may coalesce with one another. The leaves then turn yellow and fall to the ground. If the disease is serious the plants are not able to mature their nuts. This disease causes the nuts to shrivel and lie loose in the shell.

The disease cannot be controlled by spraying, as the fungus usually lives on the undersurface of the leaf and consequently cannot be reached by spraying. The disease has been controlled by introduction of foreign varieties which have proved immune to it.

Where the seed comes from an infected area it may be disinfected with a formalin solution (1 lb. of formalin in 40 gallons of water), as a precautionary measure.

Another disease which sporadically occurs in certain areas is known as root rot and is caused by a fungus *(Rhizoctonia destruens)*, which is also responsible for the root rot of potatoes

Pests.— Groundnuts are subject to attacks of various pests, but the damage done by any one of them is slight and varies somewhat in different localities. Among the insect pests attacking the crop the hairy caterpillar (*Antigastra catalaunalis*) may be mentioned.

The crop is, however, also subject to damage by white ants, jackals, wild pigs and birds. Watching and the use of scare-crows are the only remedies used in this country for these pests.

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CHAPTER XXII

ARHAR AND TUR

Origin and History.—Botanists are not definitely of one opinion regarding the place of origin of the pigeon pea (*arhar and tur*). Some botanists are of the opinion that India is the place of its origin. The majority however favour Africa in the upper regions of the river Nile. As the plant has been found wild in those parts of Africa, it seems that Africa is the more probable place of origin. The plant therefore might have been introduced into this country by the early traders who carried on trade between India and Africa. The plant has now been cultivated in this country for more than three thousand years. It is now one of the most widely cultivated pulses in India. At present it is grown in almost all the tropical countries of the world as a cultivated crop, including Africa, America, Australia, Hawaii, the West Indies and in the East Indies.

Distribution.—In this country the pigeon pea is usually grown as a mixed crop with *jowar*, *bajra*, cotton and many other crops. Statistics of the areas devoted to this crop are therefore difficult to obtain. It is however mainly grown in Bihar, the Central Provinces, Bengal, the United Provinces, Bombay, Madras and Assam.

Botanical description.—The pigeon pea (*Cajanus indicus* Spreng) is, like all pulses, a member of the family of legumes (*Leguminoseae*) Two varieties of this crop are generally recognized. The late maturing variety generally grown in Bihar, Bengal, the United Provinces and Assam and known as *arhar* is *Cajanus indicus* var. *bicolor*: The early maturing variety generally grown in the Central Provinces, Bombay and in Central India and known as *tur* or *tuar* is *Cajanus indicus* var. *flavus*. The plant is an erect shrub, and a perennial but in this country it is always cultivated as an annual as the yield of the second year's crop is too low to make it profitable as a ratoon crop. The height as well as the circumference of the plant depends on the fertility of the soil and the amount of space given to it. In good soils and a good amount of space the plant may grow to a height of 6 to 7 feet. The plant is much-branched. The branches may vary from erect to spreading, depending on the angle which the

branches make with the main stem. This habit varies with the varieties. The branches are grey-silky in colour and feel.

The leaves are trifoliate. The leaflets are entire and densely silky on the lower surface. The intensity of the green colour of the leaves varies with the varieties. The total length of the leaf and the size and shape of the leaflets also vary with the varieties.

The inflorescence is an axillary raceme often forming a terminal panicle. The flowers are distinctly papillionaceous. In the late varieties the flowers are usually grouped together at the end of the branches, but in the early varieties the flowers are produced at several points along the branches. The crop is characterized by the great extent of its flowering period, the process of flowering continuing in each plant up to the time of the harvest. The flowers are self-pollinated, pollination taking place before the flowers open. Cross-fertilization however occurs freely due to the visitation of the flowers by insects. The amount of cross-fertilization at Pusa (Bihar) has been found to vary from 0·15 to 7·59 per cent.

The crop is also characterized by the great number of flowers which it produces, but a considerable number fall off without setting, this shedding being greatly influenced by the weather conditions during the time of flowering. Damp and cloudy weather encourages shedding, whereas bright sunny days reduce it considerably.

The fruit of the pigeon pea is a pod which is usually constricted obliquely between seeds. When the pods are constricted they are termed "beaded", and when not so constricted they are termed "not beaded." The pods vary in colour from green to dark. The intermediate forms are usually green with dark maroon blotches. The seeds within the pod vary in number, but there are usually four or five in each pod in the *arhar* (late varieties) and only two or three in the *tur* (early varieties). They also vary a great deal in colour, the majority being either brown or white, but they may be also chestnut brown, purplish black, or dark mottled brown.

The root system of the pigeon pea consists of a central tap root with numerous laterals and secondary branches The length of the lateral roots also varies with the varieties, being usually longer in the spreading types than in the erect ones.

One of the reasons why the pigeon pea is commonly used in this country as a renovating crop is its deep and penetrating roots which break up the subsoil, inducing a better physical condition.

Ecological factors.—The crop usually prefers a fairly moist climate during the period of its vegetative development. It is for that reason commonly sown with the *kharif* crops. During the flowering and ripening stages of its growth it requires bright sunny weather which is favourable for the setting of fruit. One of the main characters which limits its growth in the northern parts of India is its inability to withstand frost.

The crop may be grown in almost all types of soils, but it prefers a light moist soil in which its roots can develope freely. It is grown in the black cotton soil of the Central Provinces, Central India and the Bombay Presidency as well as in the alluvial soil of the Indo-Gangetic plains When sown as a mixed crop it is usually sown in such soils as suit the other crop with which it is associated.

Classification.—The pigeon peas of India naturally fall, as mentioned above, into two groups: the *arhars* (*Cajanus indicus* var. *bicolor*) and *turs* (*Cajanus indicus* var. *flavus*).

The *arhars* are late maturing varieties. The standard, which is the largest of the five petals in the flower, possesses red veins on the dorsal side. The plants of this group are also taller than those in the other group. The pods in *arhar* also usually contain from four to five seeds.

The *turs* or *tuars* are early maturing varieties. The standard is wholly yellow and possesses no red veins. The plants of this group are usually shorter; the pods also usually contain two or three seeds.

The pigeon peas of the Central Provinces have been classified into 36 different types. More recently (1933) Shaw, Khan and Singh have classified the pigeon peas which they collected from all over the country, into 86 different types.

Cultural Methods. —The land where the pigeon pea is sown, when sown mixed with other crops, is the same as that for the crop sown with it. For instance when sown with *jowar* the land is prepared more especially to suit the proper germination of the *jowar* crop rather than that of the pigeon pea. In the same way when it is sown with cotton,

the preparation of the land is for the crop. When it is grown in lighter soils with *bajra*, the land does not require any more preparation than what is needed for the *bajra* crop.

When the pigeon pea is sown as a mixed crop, the usual custom is to sow three or four lines of the other crop between two lines of pigeon peas. When sown alone the distance between the rows varies with different localities and with the varieties *Tur* in the Central Provinces as well as in Central India is sown at a distance of about 14 to 16 inches apart between the rows In the Indo-Gangetic plain such as in Bihar and the United Provinces the distance for *arhar* may vary from 1½ to 2 feet between the rows. When sown in lines the usual method is to drop the seeds through the tube attached to the *desi* plough

When the pigeon pea is sown alone the seeds are usually broadcast.

The amount of seed used per acre when sown mixed with other crops is usually about 4 to 5 lbs. per acre, but when sown alone the amount of seed for the late maturing varieties (*arhar*) is about 12 to 15 lbs. while for the early types it is about 20 lbs.

Pigeon pea usually does not need any irrigation, but sometimes watering is given in order to protect the crop from damage by frost. The crop also does not need any weeding when sown alone, but when sown mixed with other crops, the weeds which infest the other crop are sometimes removed, as is done when it is sown mixed with cotton.

When the plants are ripe, the stalks are cut as near the ground as possible by means of sickles. They are then tied in bundles and taken to the threshing floor and allowed to dry for a few days The leaves and pods are then stripped off from the stems and heaped up in a pile. These are usually threshed by having bullocks treading on them. The other materials are separated from the grain by winnowing. The leaves and broken pods are fed to cattle while the stalks are used for roofing, basket-making, etc.

Diseases and pests—The most common disease which attacks the pigeon pea is known as wilt (*Fusarium udum*, Butl.) The disease is caused by a fungus which interferes with the upward movement of the water in the plant causing it to wither and wilt. Occasionally the disease attacks the roots, stems and branches on one side of the plant only. The disease can be easily recognized by stripping off the bark

which shows up the blackened stems clearly. In the early stages black streaks which may extend for some distance up the stem are seen. These, when traced down to the roots, will be found to have arisen from the main or lateral roots which have become rotten. Wilted plants usually occur in the field in patches. The wilting however usually appears when the plants are fullgrown. The disease seems to be more common in the Indo-Gangetic alluvium.

No practical methods of controlling this disease directly can be recommended as the disease lives in the soil. The only method of control that is possible with such diseases is the selection of resistant varieties. Such wilt resistant varieties of pigeon peas have been evolved at Pusa of which Type 51 and Type 80 are considered to be fairly resistant. The former is an erect type whereas the latter is spreading.

Another fungus disease which has been reported to attack the pigeon pea is known as the leaf spot disease of pigeon peas (*Cercospora indica*, N. Sp.) It has been found to attack this crop in Bihar and the United Provinces, where some damage is done by the disease.

The pigeon pea is also subject to attacks of various insects, the most common of which are probably the pod caterpillar (*Exelasta parasita*), the pod fly (*Muscidæ acalyptratæ*) and the leaf caterpillar (*Eucelis crittica*). The first attacks the pod, eating the seeds one after another from outside the pod; the second is a fly but the damage is done by the larva known as the maggot which feeds upon the seed; and the third is an insect which attacks usually the upper leaves of the plant by webbing them together.

No measures have been devised for the control of these insects, as the damage is not great.

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CHAPTER XXIII

BARLEY

Origin and history.—Barley is one of the most ancient of cultivated plants. There are abundant proofs that the crop was known to the Chinese, the Egyptians, and the lake dwellers in Switzerland in very remote times. The crop must also have been known in this country when the Aryans first came. The Sanskrit name *yava* (*yavaka*) which originally meant a grain and was later limited to barley, and from which the name *jav* or *jau* has been derived, shows that barley was in those very early days regarded as one of the most important grains.

Evidence seems to show that the different forms of barley must have originated somewhere in the countries extending from the northwest of India to Abyssinia. It is very probable that the centre of origin is Asia Minor and Afghanistan whence these different forms found their way through Syria and Palestine to Arabia and Abyssinia, while others spread to India.

It is today one of the most important cereals of the world and is cultivated in almost all parts of the world except the tropical regions. The leading countries in order of production are Germany, the United States of America, India, Spain, Roumania, Japan, Canada, and France. India is therefore one of the most important barley producing countries of the world, the total amount of production in 1934-1935 being 2,517,000 tons.

Distribution in India.—In this country the bulk of the crop is mainly produced in the Indo-Gangetic alluvium, the areas of greatest production being the United Provinces, Bihar and the Punjab. The United Provinces alone produces approximately 66 per cent of India's total production of barley. Its distribution according to provinces and states in this country is shown by the following table.

TABLE XXXVII

Showing the distribution of barley in India

Provinces and States.	Area in acres in		Yield in tons in	
	1934-35	1937-38	1934-35	1937-38
United Provinces	4,080,000	3,755,000	1,676,000	1,301,000
Bihar and Orissa	1,472,000	1,301,000	570,000	462,000
Punjab	612,000	777,000	168,000	206,000
North-West Frontier Provinces ..	130,000	179,000	41,000	55,000
Bengal	91,000	95,000	30,000	30,000
Ajmer-Merwara	48,000	52,000	12,000	16,000
Bombay	19,000	15,000	6,000	4,000
Hyderabad State	36,000	13,000	5,000	2,000
Sindh	15,000	18,000	3,000	4,000
Central Provinces and Berar ..	14,000	15,000	3,000	3,000
Delhi	9,000	15,000	3,000	5,000
Total ..	6,526,000	6,245,000	2,517,000	2,089,000

Botanical characters.—Barley belongs to the genus *Hordeum*, and like all cereals is a member of the grass family (*Gramineæ*). As a plant, it very much resembles wheat, but differs slightly from the latter in the length of the stems, the character of the leaves, and the structure of the spike. The stems possess from five to seven inter-nodes. The height of the plants varies with environmental conditions and with the variety but in general the average height is from two to three feet, which is shorter than wheat. The degree of tillering is usually as great as that in wheat. Lodging is not as common as in wheat. This latter character is probably due to the fact that in this country barley is usually grown in poor soils where wheat cannot grow well, and not to the inherent strength of the barley stems as compared with those of wheat.

The leaves of barley also resemble those of wheat but are usually broader, and the colour of the leaves is not as deep green as that of the leaves of wheat, being usually light green. The leaves of barley

possess very conspicuous auricles which are larger than those in wheat.

The inflorescence consists of a terminal spike, the shape of which varies slightly in different species, as for instance in what are called the two-rowed, the four-rowed and the six-rowed barleys. In barley three spikelets occur at a node on the rachis, a character which distinguishes it from wheat which possesses only one spikelet at a node on the rachis. In the six-rowed type, which is the most common in India, the spikelets are in six distinct rows and stand out equidistant from the rachis, all the spikelets being fertile and producing grain. However, whereas barley has only one floret in a spikelet, wheat usually contains thre or more, and oats generally two or more. In the two-rowed barleys the spikes bear two longitudinal rows of grains. This is due to the fact that the outer spikelets at each node are infertile and only the central floret produces grain. In this way four rows are eliminated leaving only two. The four-rowed or common barley of western countries does not occur in this country.

Barley is normally self-pollinated, and natural cross-fertilization seldom occurs. The reason for this probably is that the styles are short and do not protrude beyond the glumes Natural crossing does not occur in the two-rowed types. This is probably due to the fact that the flowers in the two-rowed barleys are known to open even before the ears emerge from the terminal leaf-sheath. The time required to head out for all the tillers in an individual plant depends largely on the variety, the vigour of the plant and the number of tillers per plant.

The grain of barley is a caryopsis, and, unlike wheat, usually adheres to the lemma and the palea or hull. In some varieties however, which are known as naked barleys this condition does not occur. The grain in barley is usually larger and more uniform in the two-rowed than in the six-rowed types; but. the yield in the latter is usually greater.

The root system of barley consists of two more or less well-defined groups, the shallow and the deep roots. The shallow roots arise near the surface of the ground and spread out laterally almost at right angles to the tillers. The deep roots extend downwards into the deeper layers of the soil. In the shallow-rooted type of barley there

is a greater development of the shallow roots, whereas in the deep-rooted types there is a greater proportion of the deeper feeding roots. The shallow-rooted types of barley have been found to be more common in Bihar and other localities with abundant soil moisture, whereas the deep-rooted ones are found in the drier tracts such as the United Provinces, Rajputana, the Punjab and Sind. It has also been found that the shallow-rooted types are earlier than the deep-rooted ones. The former are also erect or semi-erect while the latter, that is the deep rooted ones, have a tendency to be spreading or bushy.

Ecological factors.—Barley is a plant that can grow fairly well in temperate as well as in sub-tropical regions of the earth. It does well in such countries as Germany and Ireland in the temperate regions as well as in Arabia and India, in the hotter sections of the globe. It is therefore adapted to varying conditions of climate and soil. In India it is cultivated in the plains as well as in the higher regions of the Himalayas up to 14,000 feet. It, however, does not thrive well in the warm and humid regions of the country such as in Madras, Bengal and Assam. It is therefore a crop which requires a warm and dry climate. It requires less water than either wheat or oats, and also a shorter growing season. Because of the latter character it is possible to grow it in the northern regions of the world. Barley also can withstand more alkalinity in the soil than wheat. In most parts of the United Provinces it is grown in soils which are too light or otherwise not very favourable for the growth of wheat. But while barley will grow well on poor soils, it does best on soils that are well supplied with fertilizing elements.

Classification.—The barleys have been classified by several workers since the time of Linnaeus, but the classification by Harland in 1918 seems to be the most satisfactory. His key for the common cultivated barleys is as follows :

Key to the Species

A. All spikelets fertile (6-rowed barley).

B. Lemmas of all florets awned or hooded.......................... *vulgare* L.

BB. Lemmas of lateral florets bearing neither awns nor hoods.. *intermedium* Kcke.

A . Only the central spikelets fertile (2-rowed barely).

B. Lateral spikelets consisting of outer glumes, lemma, palea, rachilla and usually rudiments of the sexual organs............... *Dist chon* L.

BB. Lateral spikelets reduced, usually to only the outer glumes and rachilla, rarely more than one flowering glume present, and never rudiments of sexual organs .... *Deficiens* Steud:

As mentioned previously in this chapter, the two forms of barley which occur in this country are the six-rowed and the two-rowed barleys; but of the six-rowed types, *Hordeum vulgare* L. and of the two-rowed barleys, *H. distichon* include all the types which occur in this country. According to Bose, who has classified the Indian barleys, *Hordeum vulgare* is sub-divided into the variety *Pallidum* the hulled barleys, and the variety *Caeleste*, the hulless barleys. In the former there are altogether 18 different types, but *Caeleste* is represented by only one type. The two rowed barleys have been classified by him into five different types. Thus there are, according to him, 24 separate types altogether.

Cultural methods.—The preparation of the land for the cultivation of barley is not as thorough as in the case of wheat. The number of ploughings is much less than in the case of wheat. Using an improved plough, one ploughing followed by harrowing is regarded as sufficient preparation for the seed bed for barley.

In most parts of the United Provinces and the Punjab barley is frequently sown mixed with gram, and the combined crop is known as *berra* Occasionally it is also sown mixed with such crops as wheat, linseed, peas and mustard.

When sown alone the amount of seed per acre varies from 60 to 120lbs. The high seed rate is probably necessary because of the deterioration of the seed in storage. This is believed to be due to the exposure of the seed to high humidity during the monsoon.

Barley is usually sown in the United Provinces more or less at the same time with wheat, but it may also be sown earlier or later. The crop takes less time to mature than wheat. Hence when sown in October it is generally harvested in March or in the beginning of April.

Weeding is not generally practised, and irrigation is seldom given.

The method of harvesting is also similar to that of wheat. It consists in cutting the crop with sickles when fully ripe. But as the

crop shatters more easily than wheat, it is usually harvested in the forenoon before the h'ads become too dry and fragile for handling. The crop is then taken to the threshing floor where the bullocks are made to tread o it. The grain is separated from the chaff by winnowing.

Diseases and pests.—Barley is subject to a number of fungous diseases of which the most common and more widely distributed in this country is probably the covered smut (*Ustilago Hordei*). The other diseases which are also found to attack the crop are loose smut (*Ustilago nuda*); rusts (*Puccinia simplex*, *Puccinia graminis* and *Puccinia glumarum*), *Helminthosporium* diseases caused by *H. gramineum* and *H. teres*, and powdery mildews (*Erysiphe graminis*). With the exception of covered smut, the rest are probably of minor economic importance.

Covered smut appears in the ears of barley as black covered masses, which are spores of the fungus enclosed within an ovary wall. There are several methods adopted for the control of this disease, but the most common is the use of a formalin solution (1lb. of commercial formalin in 40 gallons of water). The seed is moistened by sprinkling and is kept moist for four hours.

Barley is more or less free from the attack of insect pests. But in general those that attack wheat would also attack barley.

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CHAPTER XXIV

BAJRA

Origin and history.—The origin and history of *bajra* is still very imperfectly known. It seems very probable, however, that the plant originated either in India or Africa, as the crop is widely cultivated in the various regions of the two places mentioned. But the crop is also cultivated in Arabia and Southern Europe, and more recently has been introduced into the United States of America, where it is being grown mostly for fodder purposes.

Distribution in India.—In India, the crop is grown in most parts of the country except Eastern Bengal and Assam. It is generally grown in areas of low rainfall and in soil too poor for *jowar*. The following table shows the distribution of *bajra* in provinces and states of India.

TABLE XXXVIII

Showing the distribution of bajra in India.

Provinces and States.	Area in acres in		Yield in tons in	
	1934—35.	1937—38	1934—35.	1937—38.
Madras	2,697,000	2,572,000	627,000	663,000
Bombay	3,946,000	3,542,000	482,000	419,000
United Provinces	2,159,000	2,096,000	451,000	323,000
Punjab	3,043,000	2,615,000	355,000	239,000
Hyderabad	2,112,000	2,108,000	128,000	124,000
Sind	873,000	842,000	101,000	103,000
Bihar and Orissa	68,000	62,000 5,000	26,000	26,000 1,000
Central Provinces and Berar ..	93,000	101,000	19,000	26,000
North-West Frontier Province .	146,000	94,000	14,000	18,000
Delhi	49,000	49,000	11,000	7,000
Mysore	54,000	66,000	9,000	7,000
Others	1,236,000	2,034,000	326,000	593,000
Total ..	16,476,000	16,186,000	2,549,000	2,549,000

The figures given above do not show the acreage and total production from the Rajputana States, as figures are not available. But in general, it may be said, that the area under *bajra* in the drier parts of Rajputana represents about 40 to 60 per cent of the total cultivated area in those regions

Botanical description.—*Bajra* is a member of the family of grasses (*Gramineae*). Several scientific names had been given to it in the past, but the one most commonly adopted at the present time is *Pennisetum typhoideum.* It is known in English by several names such as pearl millet, cat-tail millet and bulrush millet. In India also it is called by the name of *cumbu* or *sajja* in South India, or *bajri* in several parts of northern India.

The stems of *bajra* stand erect and are usually 3 to 8 feet tall. Tillers are not common but they may sometimes arise, depending usually on the spacing and also on the variety. The plants also sometimes produce axillary branches, but these are not as vigorous as the tillers and may only develope two or three internodes. It has been found that conditions favouring tillering are also favourable for the development of branches.

The leaves of *bajra*, like those of all grasses, consist of a blade or lamina and a sheath. The blade is lanceolate and long-pointed, and possesses numerous hairs on both surfaces. The sheath which is a little thicker than the lamina clasps the stem almost completely. The ligule, which is a structure at the juncture of the blade and the sheath and occasionally known as the rainguard is about four or five mm. in length.

The inflorescence of *bajra* is a compound spike with an unbranched tapering central axis. The length of the inflorescence is usually six to fourteen inches, except in one variety, known as Jamnagar Giant whose inflorescence is about 2 feet or more in length. The branches on which the flowers are borne, known as rachillae, may contain from two to five spikelets each, but the most common number is two. The inflorescence bears two types of flowers, hermaphrodite and staminate. The former are the first to appear.

Soon after the emergence of the inflorescence (head), the styles beign to protrude out of the glumes. The anthers begin to push out

after the styles have started to dry up. This protogynous nature of the inflorescence makes the plant more susceptible to cross-pollination. It can therefore be safely assumed that there is a great deal of cross-fertilization taking place in this crop.

The seed is a small grain about 3 to 4 mm. long and 3 to 10 mgm. in weight. It is somewhat flattened on the sides, but more or less oval in appearance, with one end somewhat tapering. The colour of the seed varies from pale yellow to dull light blue.

The root system is, like that of most grasses, fibrous. The roots which go downwards are generally thicker than those which spread out laterally. But on the whole the plant is shallow-rooted and may be considered as a surface feeder.

Ecological factors.—*Bajra* is grown in India as a *kharif* (monsoon) crop, but more usually as a catch crop; that is, it is grown when the amount of rainfall during the *kharif* season has not been sufficient for other crops like *jowar*. The plant, therefore, does not require very much water and will thrive best in sandy loams, or well drained light soils. *Bajra* can also grow well in soils which are too poor for most other cereals.

The crop will do best under conditions of light showers followed by bright sunshine during the period of its growth.

Classification.—*Bajra* has not been classified systematically like most other crops. The characters considered in naming local varieties are the length of the head or spike, the presence or absence of awns, that is, whether hairy (bristled) or non-hairy, and the number of days the plants take to mature, that is, whether early or late.

Cultural methods.—The preparation of the land on which this millet is to be sown is not as thorough as for the seed bed for *jowar*. The land is usually ploughed two or three times before sowing. The seed is usually sown mixed with other crops, more usually pulses such as the pigeon pea, *urd*, and *mung*, or with sesamum, etc. The seeds are either broadcast or sown in lines. The amount of seed used per acre when sown alone varies from six to ten pounds, but when sown with other crops it is much less. The crop ordinarily is not weeded, and no irrigation is given.

The crop, when grown for grain, is harvested when the heads are ripe, but when grown for fodder, it is cut before the stalks become too

dry. The plants are cut by means of sickles as near the ground as possible, and the heads are taken to the threshing floor where the bullocks tread the seed out. The grain is cleaned by winnowing.

Diseases and insect pests.—The most common disease which occurs on *bajra* in this country is known as the "green ear" disease. This is caused by a fungus known as *Sclerospora graminicola.* The disease, as the name suggests, usually appears in the form of a mass of small twisted green leaves instead of the grain in the spike or head. The disease may affect part or all of the head. In severe cases, only shredded leaves may appear in place of the head. In the early stages of the growth of the plant the leaves appear whitish and later turn brown.

The disease occurs almost everywhere where *bajra* is grown, but the attack usually is not very serious.

The only method of control known is the prevention of the dissemination of the spores, by the removal of affected plants.

The other diseases that are known to damage *bajra* plants are rust (*Puccinia Penniseti*) and smut (*Tolyposporium Penicillaria*).

No insects are known seriously to damage the *bajra* crop.

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CHAPTER XXV.

MAIZE

Origin and history.—Maize is undoubtedly of American origin. The plant has not been found in the wild state, but it is generally believed that teosinte (*Euchlaena Mexicana*) with which it is known to cross readily is its ancestor. Its introduction into India probably occurred about the beginning of the seventeenth century during the early days of the East India Company. The crop is now cultivated almost throughout the country, and is the staple food of a large number of people in northern India in the hilly tracts.

Maize is now grown mostly in the United States of America, Argentina, Roumania, Italy, India, Hungary, the Union of South Africa and Egypt.

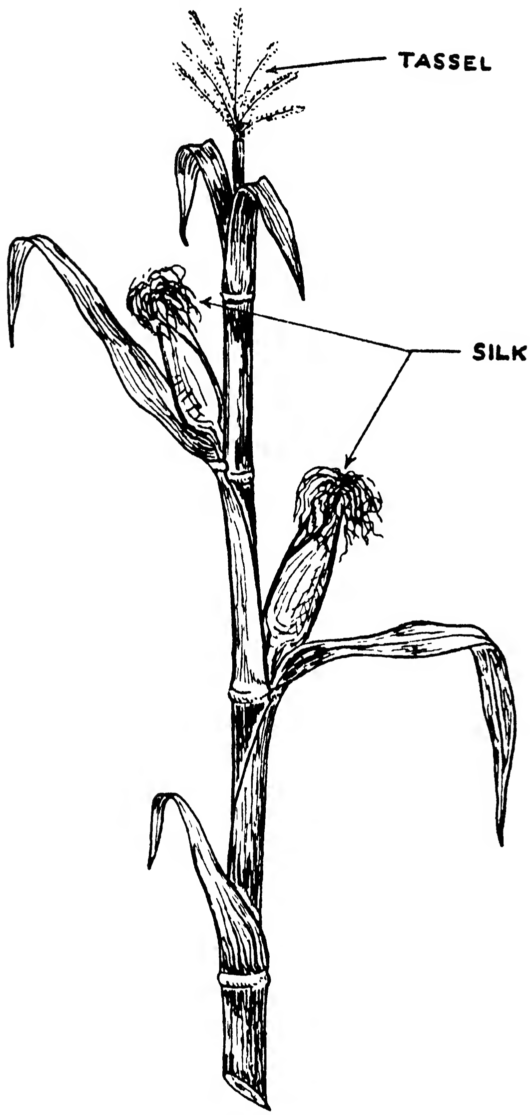
Distribution in India.—The following table shows the distribution of maize in the provinces and states of India.

TABLE XXXIX

Showing the distribution of Maize in India.

Provinces and States.	Area in acres in		Yield of grain in tons in	
	1934—35	1937—38	1934—35	1937—38
United Provinces .. .	2,121,000	1,948,000	796,000	730,000
Bihar and Orissa	1,654,000	1,553,000 29,000	468,000	445,000 7,000
Punjab	1,136,000	1,103,000	412,000	406,000
North-West Frontier Province ..	475,000	471,000	213,000	220,000
Hyderabad State	712,000	651,000	120,000	108,000
Central Provinces and Berar ..	156,000	152,000	100,000	88,000
Bombay	174,000	164,000	75,000	49,000
Madras	69,000	72,000	29,000	31,000
Bengal	75,000	74,000	23,000	24,000
Ajmer-Merwara	59,000	52,000	14,000	11,000
Others	224,000	7,000	49,000	2,000
Total ..	6,855,000	6,276,000	2,299,000	2,121,000

Botanical description.—Maize (*Zea Mays*) is a member of the family of grasses (*Gramineae*). It is a tall herbaceous annual, but its height is very variable, more so than that of any other cereal. The average height varies from 5 to 10 feet but some may attain a height of 25 feet or more.



Part of the maize plant showing the pistillate and staminate flowers.

The stem is made up of a succession of nodes and internodes, and unlike the stems of most cereals, it is completely filled with pith. The internodes are somewhat flattened or grooved on the side next to the leaf-sheath.

Maize plants often produce tillers. This habit of tillering has been found to be hereditary, but is also greatly influenced by soil and climatic conditions.

The leaves of maize develop alternately on opposite sides of the stem. The number of leaves varies from 10 to 20. The width varies greatly with varieties.

The inflorescence in maize is of two types: (1) the pistillate inflorescence which developes into an ear, and (2) the staminate inflorescence which contains the male flowers. The pistillate or female inflorecences are borne at the side of the plant usually above the middle of the stem, but the staminate or male inflorescence always occurs at the top of the stem. The number of pistillate inflorescences in a single plant, that is the number of ears, may be more than one per

stalk, but the staminate inflorescence is always terminal and therefore only one per stalk.

The pistillate inflorescence is borne on a short branch called the "shank." The branch bears modified leaves which enclose the ear and are collectively known as the 'husk." The pistillate spikelets are borne on a thick axis called a "cob." Each pistillate spikelet produces two flowers, one of which is abortive. The other flower bears the usual parts of a pistillate flower, which include the glume and palea, an ovary, the style and stigma. The ovary develops into a mature kernel; the styles are very long, and emerge through the husk and are collectively known as the "silk"; the stigma is the receptive portion at the end of the style.

Maize is ordinarily cross-pollinated, but self-pollination frequently occurs. Pollination may be brought about by wind or gravity.

The grain of maize is a mature ovary, and is, therefore, morphologically a fruit; that is, the ovary wall adheres tightly to the seed coat.

The root system of maize is usually well developed. The lateral roots branch profusely, spread widely, and penetrate deeply into the soil. But the depth to which the roots penetrate or the distance to which they spread is greatly influenced by the moisture conditions in the soil. In somewhat dry soils the roots penetrate deeply.

Besides these ordinary roots, maize possesses another type known as adventitous roots. These arise above the surface of the soil on the first two or three nodes and grow obliquely downwards penetrating the soil and help to anchor the plant more firmly into the soil. Hence they are sometimes known as "prop" or "brace" roots.

Ecological factors.—Maize is grown in many parts of this country as a *kharif* crop. It is a crop that requires plenty of moisture in the soil during the early stages of its growth, followed by sunshine. The crop, if stunted during the early stages of its growth due to a lack of moisture, will not be able to recuperate fully, and will therefore remain more or less stunted. The distribution and amount of rainfall in July and August greatly influence the yield.

The soil best suited for the growing of maize is a well-drained fertile soil. It will not do well on heavy clay soils, nor on very light soils.

Classification.—Maize (*Zea Mays*) has been divided into six classes, mainly on the character of the horny endosperm, and whether the husk covers the individual grains or not. The following key is given as an aid for the recognition of these classes.

*Key to the "classes" of maize.

A. Husk covering each individual kernel.... ....*Zea Mays tunicata.*
AA. Husk not covering each individual kernel.
  B. Grain possessing exceptional popping properties... ...*Zea Mays everta.*
  BB. Grains with little or no popping properties.
    C. Grains soft........... ....*Zea Mays amylacea.*
    CC. Grains hard.
      D. Grains shrivelled or wrinkled...........*Zea Mays saccharata.*
      DD. Grains smooth.
        E. Kernels dented on top ....*Zea Mays indentata.*
        EE. Kernels not dented on top...........*Zea Mays indurata.*

1. *Zea Mays tunicata* is a primitive type and is not grown commercially. This is sometimes known as pod corn in America.

2. *Zea Mays everta* is commonly known as pop corn in America as it possesses exceptional popping qualities. The ears are small, and kernels are small and pointed. This is an exotic variety in this country.

3 *Zea Mays amylacea* is sometimes known as soft corn as it does not possess a hard endosperm, and in the absence of which the kernels become soft.

4. *Zea Mays saccharata* is the common sugar or sweet corn, and is usually grown in home gardens. The grains possess a considerable amount of sugar which makes them shrivelled or wrinkled when they are dry.

5. *Zea Mays indentata* or dent corn is so called because of the dent or pit-like formation on the top of the grain. This is the most common type of maize in the United States of America.

6. *Zea Mays indurata* or flint corn, as the name suggests is very flinty or hard and smooth. It is the type most commonly cultivated in India.

*Adapted from Robbins "Botany of crop plants."

Cultural methods.—In the plains the usual method of preparation of the land for sowing is to plough the land after the first shower of rain two or three times. The land should also be well manured. The seeds are then either sown in lines or broadcast. When sown in lines the distance between them is about 18 inches, and the distance between plants in the lines is usually 9 inches. The amount of seed per acre is usually about 10 to 15lbs. Occasionally the seeds are sown by dropping them in a furrow made by a plough.

Maize is sometimes grown as an irrigated crop, especially near large cities where it is grown for the green ears used as vegetables, and when an early crop is wanted.

Maize requires thorough weeding and usually two or three cultivations during its growth.

If maize is grown for green ears, the ears are harvested while they are still green, and the stalks are cut and fed to cattle. When grown for seed it is best to leave the ears in the field until they are fully ripe. The ears are then harvested by breaking them off the stalks, and are allowed to dry. This is usually done near the cultivators' home where they can be carefully watched. When dry, the grain is shelled from the cobs usually by hand. When kept for seed it is best to store the seed on the cobs in dry and well ventilated room. The stalks left in the field are cut as near the ground as possible by sickles and tied in bundles and later made into *kadbi* (chopped fodder) and fed to cattle.

Diseases and pests.—The maize crop in India is subject to the attack of several fungous diseases. Some of which are: (1) the head smut (*Ustilago Reiliana*) which attacks the male as well as the female inflorescence, causing the tassel or the ear to be converted into a mass of black spores or smut; (2) the common smut of maize (*Ustilago Zeae*), which causes tumours in place of grains on infected plants; (3) the downy mildew (*Sclerosporo Maydis*), which usually attacks the young seedlings, making the infected parts of the plants whitish in long streaks; (4) the rust (*Puccinia Maydis*) which appears on the leaves as innumerable rusty brown spots, causing the plants to droop; (5) leaf blight (*Helminthosporium turcicum*) which appears on the leaves as small yellowish round or oval spots; and (6) a disease caused by *Colletotrichum graminicolum* which appears in the form of small brownish spots on the upper side of the leaves.

These diseases are not known to do very serious damage to the crop, except in very restricted localities The control of most of these fungous diseases seem to lie in the direction of the selection of resistant strains.

The insect pests which attack maize are usually those which also attack *jowar* and sugar cane, and have, therefore, been dealt with in connection with those crops.

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CHAPTER XXVI

SESAME OR TIL

Origin and history.—Sesame, according to most investigators, originated in southern and southwestern Africa, where all the wild and cultivated species of the genus *Sesamum* are found to occur. From there it is believed to have spread northward to Abyssinia whence it found its way into India, probably before the Aryans came into this country.

The diversity of ecological factors in this country is believed to have given rise to a multitude of forms which spread eastwards to China, Indo-China and Japan and westwards through Afghanistan to various parts of Western Asia, the Mediterranean regions and to Northern Africa. Thus India is a secondary centre of origin of the multitudinous forms now cultivated in various parts of the world.

Distribution in India.—Sesame is grown in all parts of India. The areas where it is most intensively cultivated are in Burma, but its distribution in India according to provinces is as given in the table below.

TABLE XXXX

Showing the distribution of sesame in India

Provinces and States.	Area in acres in		Yield in tons in	
	1934-35	1937-38	1934-35	1937-38
Madras	653,000	795,000	79,000	77,000
Bombay (including States) ..	580,000	544,000	57,000	76,000
Bengal	158,000	210,000	35,000	46,000
Bihar and Orissa	202,000	114,000 112,000	30,000	17,000
Central Provinces and Berar ..	386,000	483,000	23,000	40,000
United Provinces	242,000	368,000	22,000	32,000
Hyderabad	509,000	548,000	22,000	40,000
Punjab	103,000	95,000	8,000	7,000
Baroda	69,000	53,000	3,000	3,000
Others	2,320,000	1,134,000	129,000	111,000
Total	5,222,000	4,456,000	408,000	449,000

Botanical description.—Sesame belongs to the genus *Sesamum*, one of the 14 genera of the *Pedaliaceæ* or pedalium family, of which *Sesamum indicum* is one. The plants in the family are covered with peculiar slime-secreting glands.

Sesame is a herbaceous annual with an average height of about three to four feet. Certain strains, however, may reach a height of about 6 feet. The stems are erect, angular and striate. The upper part of the stem is particularly covered with short hairs. Branching varies widely with different types; some do not branch at all, whereas in the branched varieties the degree of branching varies considerably. Some branch profusely, the primary branches beginning near the base and continuing upwards almost to the top of the main stem. Similarly these primary branches produce secondary branches. This profuse branching gives the plant a bushy appearance in certain varieties. The unbranched varieties flower early and consequently require a short growing period, whereas the bushy types flower late and therefore require a longer growing period.

The leaves may be entire or divided. When divided, they may be slightly or deeply incised or dissected. The leaf margins may be entire or dentate. The leaves also vary greatly in width, some being narrow, others intermediate, broad or very broad. The arrangement of the leaves on the stem may be opposite, alternate or mixed. The shape and size of the leaves also vary considerably in the same plant. Usually the lower leaves are the broadest while the upper ones are narrow. The surface of the leaf is generally glabrous but in some it may be pubescent. The colour of the leaves also varies from light to dark green.

The inflorescence is a raceme, and the flowers are borne in acropetal succession, in the axils of the upper leaves, either singly or in groups of two or three. The flowers vary in size and colour and in the makings inside the tube, but are always hairy. The flower is tubular and two-lipped, composed of five lobes, the two lobes of the upper lip being shorter than the three lobes of the lower. The colour of the corolla varies from white through pink to purple. The hairs on the corolla may be short, intermediate or long.

In sesame, self-pollination is the rule, but considerable natural cross-fertilization takes place, in which it is believed that insects, parti-

cularly bees, play a part. The amount of natural cross-fertilization at Lyallpur in the Punjab has been estimated to be about five per cent. One of the peculiar phenomena which commonly occurs in the flowers of sesame, is the modification of the flowers in various ways causing sterility. This phenomenon is known as sepaloidy.

The number of locules in a capsule may vary from four to six, eight or occasionally ten. The number of locules in the same plant may vary.

The fruit of sesame is a capsule in which the number of carpels may be two or four. The varieties therefore belong to one or other of the sub-species *bicarpellatum* or *quadricarpellatum*.

The arrangement of the capsules on the stem may be lax, intermediate or dense Numerous seeds are borne in the capsule. These vary greatly in colour and size and in the surface of the seed-coat. The common colours are white, brown and black and their various shades. The size of the seed may be small, medium or large, and the seed-coat is either rough or smooth.

In sesame two types of root systems are recognized In the early-maturing types, the root system is poorly developed. The depth to which the roots penetrate the soil is about three feet. They bear only a few secondary and tertiary roots In the late-maturing varieties, the main root goes deeper and bears an enormous mass of secondary and tertiary roots near the surface of the soil. So there is a distinct correlation between root and shoot development.

Ecological factors.—The cultivation of sesame extends beyond the tropical countries where short-season varieties are grown. In India it is grown in the colder regions as a *kharif* crop and in the warmer regions as a *rabi* crop. The crop will do best in a well-drained fertile soil, but more often it is grown on poor and lighter soils. Continued heavy rain is detrimental to its growth.

Classification.—The first serious attempt at the classification of the Indian sesames is that by Kashi Ram in 1930. He classified them on the basis of the number of flowers in a leaf axil, seed colour, corolla colour and markings, and the time taken to reach maturity. On the basis of this classification he classified thirty different types.

Using more or less the same method of classification, Ali Mohammad and Zafar Alam in 1933, classified thirty four different types of sesame in the Punjab.

Rhind and Thein, also in 1933, working with the Burmese sesames, classified them into forty-nine different types mainly on the basis of the maturation period (late or early), presence or absence of branches, colour of seeds, and number of capsules in an axil.

A more extensive classification of the world sesames was made by the Russian workers of the Institute of Applied Botany, who collected specimens from all parts of the world. According to this classification the cultivated sesames were divided into two main groups on the basis of the number of carpels in the capsule, that is whether two or four, which are called subspecies *bicarpellatum* and *quadricarpellatum* respectively. The former was further sub-divided into 79 varieties, and the latter into 32. Out of the total samples collected, 28 were Indian varieties.

Cultural methods.—The crop is cultivated as a *kharif* crop in the colder parts of the country and as a *rabi* crop in the warmer parts. When grown as a *kharif* crop, it is usually sown in June and July and harvested in October and November. But when grown as a *rabi* crop it may be sown in September or October. In Madras, if irrigated it may be sown in January or February. The method of preparing the seed bed consists in ploughing two or three times, but the preparation is not as thorough as for most of the *kharif* and *rabi* crops. The crop is usually grown with other crops such as *jowar*, *bajra*, or cotton and it gets the benefit of the care which these crops receive. Whether sown alone or mixed with other crops, the seed is generally sown broadcast, or sometimes it is sown in parallel lines across the field or along its borders. When sown alone the amount of seed per acre is about 16 to 20 lbs., but when sown mixed it requires much less.

The crop is harvested before the plants are fully ripe. This prevents shattering and the dropping of seeds from the open capsules. The plants are cut with sickles, tied in bundles and taken to the threshing floor where they are stacked upright. After several days (about a week) when they are dry, the heads are turned downwards and shaken. The seeds all fall out from the open capsules. If all the capsules are not open, this operation may have to be repeated. The seed is then cleaned by winnowing.

Diseases and pests—The crop is practically free from the attacks of fungi. The peculiar phenomenon, described previously in this chapter, and called sepaloidy is believed by some to be caused by a virus.

The only pests known to do some damage to the sesame crop in this country are (1) the "til sphinx" (*Acherontia styx*) which is a large green caterpillar with yellow stripes and a horn-like projection on its hind end, and (2) the caterpillar of a moth known as *Antigastra catalaunalis*.

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CHAPTER XXVII.

MINOR LEGUMES

Some of the important leguminous crops grown in this country have been dealt with in previous chapters. In the present one are included those leguminous crops which are of comparatively minor importance in this country. These are: (1) sunn-hemp, (2) lentil, (3) *mung*, (4) *urd*, (5) cowpea, (6) soybean, (7) peas, (8) *khesari* and (9) *moth.*

SUNN-HEMP.

Sunn-hemp (*Crotalaria juncea*) has probably been grown in this country from very early times. It is found throughout the plains of India and is grown either as a fibre crop or as a crop for renovating the soil.

It is difficult to get estimates of the total acreage under this crop since it is usually grown in long strips around fields, and is sometimes classed under "fibres" or under "hemp".

The plant grows to a height of about four to eight feet depending on the fertility of the soil. Its branches are slender and somewhat silky. The leaves are rather far apart on the stem, shining, and with short silky hairs. The inflorescence is a raceme usually of twelve to twenty yellow flowers. Extensive cross-fertilization takes place in this crop, and self-pollination has been found not to occur if the stigmatic surface is not stimulated by insects or by some other means.

In most parts of India sunn-hemp is a *kharif* crop, being sown at the beginning of the rains, but in Madras it may be sown as early as February. The type of soil on which it is generally grown is a light loam. It is not grown on heavy clays or on water-logged soils.

Whether the crop is grown for fibre or for green-manuring, a quick growth is necessary. This is obtained by a thorough preparation of the seed bed. Ploughing usually begins with the first rains, and the seed is sown as soon as the soil is moist enough for the proper germination of the seed. The amount of seed per acre whether sown for fibre or for green-manuring is practically the same. But the exact amount

varies with different localities, 50 lbs. being about the average used per acre. After the sowing of the seed, usually the crop requires no more care or weeding.

When grown for green-manuring the crop, when about 2 or 3 feet high, is run over by a heavy beam or planker in order to make it lie flat on the ground in the direction in which the ploughing will be done. The crop is then ploughed under by means of a mould-board plough. This operation should be done while the plants are still succulent and while the ground is quite moist in order to ensure the rapid decay of the crop.

When grown for fibre the crop is sometimes harvested when in full bloom. In other cases it is allowed to remain in the field until the fruits have developed or in some cases until the crop is dead ripe. The best fibre is believed to be obtained when harvested before the plants are quite ripe. Harvesting is done by cutting the plants as near the ground as possible by means of sickles. The cut plants are allowed to remain in the field exposed to the sun for two or three days until the leaves have shed. The stalks are then tied in bundles of convenient size and stacked for some days. The bundles are then placed in water about two feet deep, only the lower portions being covered. This is to allow the thicker portions more time for retting. Later the whole bundles are immersed, weighted down, and left until the bark separates easily from the stem. The plants are then taken out and dried, and the fibre is extracted by hand.

One of the diseases which commonly attack this crop is known as wilt and is caused by a fungus (*Fusarium vasinfectum*). The only method of control which is followed at present is the growing of resistant strains. A strain evolved in the Uuited Provinces and known as Cawnpore 12 is reported to be fairly resistant to this disease.

LENTILS OR MASUR

The lentil (*Lens esculenta* Moench) is one of the most ancient cultivated plants. Linnaeus called it *Ervum lens.* But modern botanists are inclined to include the genus *Ervum* as but a section of the genus *Vicia*, and to separate the lentil into another genus. The scientific name *Lens esculenta* is used here.

According to Helena Barulina, the centre of origin of the cultivated lentil is probably the region between the Hindu Kush mountains and the Himalayas. Its area of cultivation embraces several countries in Asia, Europe, Africa and in North and South America.

In India it is cultivated in most parts of the country, but it is grown more especially in the Central Provinces, Madras, the United Provinces, Bengal and Bihar.

Lentils are annual herbaceous plants varying in height from about 6 to 24 inches, and are usually more are less erect, the general habit of the plants depending on the mode of branching, the height and the amount of foliage. The stems are usually angular and possess short hairs, the degree of hairiness varying with different varieties. The stems may be entirely green or possess anthocyan in pigments at the base.

The leaves are pinnately compound with 2 to 8 pairs of oval or linear leaflets, and terminating in a tendril. The leaves are also stipulate.

The inflorescence is a raceme consisting of 1, 2, 3, or occasionally four flowers. The colour of the flowers may be white, pink or violet, the most common being white with violet-blue veins of varying intensities. Self-fertilization is the rule, but natural cross-fertilization may occur due to the visitation of such insects as bees and butterflies.

The root system has been found to be of three types. One type which represents the group grown in the black cotton soil is a deep root system with few laterals near rhe surface of the soil. Another type which represents the group found in the Gangetic alluvium is a shallow root system, but with well-developed laterals near the surface of the soil. The third type is intermediate between these two and represents the group found in the Indus alluvium in the Punjab and the Northwest Frontier Province.

The lentil crop is grown over a very wide range of climate and soil. In this country it is generally grown as a cold season crop mostly on the low-lying lands.

The lentils of this country have been classified by Shaw and Bose, mainly on the basis of the seed colour, the degree of mottling

of the seed, the colour of the hilum, size of the seed and the colour of the flowers. According to this classification, 66 different types of lentils have been identified.

Helena Barulina has classified the lentils of the world into two principal geographical groups or subspecies known as *macrosperma* and *microsperma*. The first are large-seeded, and the latter are small-seeded. The main characters which also distinguish these groups are the size of flowers, pods and seeds, and the shape of the pods. These groups are further divided on the basis of such characters as "the degree of dehiscence of the pods, pubescence of the plants, relative length of the calyx teeth, number of flowes per peduncle, character of branching and colour of flowers" In this classification 39 different characters were used, instead of 7 or 8 used by Alefeld who first made an attempt in the classification of lentils.

The seed bed for the sowing of this crop is roughly prepared, two or three ploughings being considered sufficient. The seed is then sown broadcast at the rate of about 20 to 25lbs. per acre when sown alone. But when sown mixed with such crops as barley and mustard the amount of seed is approximately half of the usual seed rate. Harvesting, threshing, and winnowing is done as in the case of most *rabi* crops.

The lentil crop in this country is usually subject to an attack of rust caused by *Uromyces Fabae*, a fungus which is known to attack peas also. The damage done by this fungus on the lentil crop is, however, usually slight.

Lentils, however, are associated with a weed known as vetch (*Vicia* sp.) which is very similar in appearance to the lentils and *khesari* (*Lathyrus sp.*). Their presence in the crop is sometimes considerable and consequently impairs its quality. The similarity of the weed to these crops is an outstanding example of mimicry in plants, and affords a very good example in support of the "Law of Homologous Series" as applied to plants, and first enunciated by Professor N. I. Vavilov.

As an aid to the identification of these three genera of legumes, the following key is given below, which is adapted from Bailey.

A. Wings of corolla free, or essentially so, from keel.................*Lathyrus*

AA. Wings of corolla adherent to keel, half or more their length.

B. Lobes of calyx long subulate, style bearded down inner face........*Lens*

BB Lobes of calyx short and broad, style bearded in tuft or ring at the apex...*Vicia*

MUNG OR GREEN GRAM

Mung or green gram is probably indigenous to this country. Its cultivation in Africa is of a more recent date. It is an important crop only in this country and to some extent in South Eastern Asia. Its cultivation in India is widespread, but it is grown as a minor crop in association with other crops like cotton, maize, *jowar* and other millets.

The scientific naming of *mung* has been considerably confused, but it seems that the consensus of opinion among botanists is that the name *Phaseolus radiatus* Linn. should be applied to it, and that the scientific name *Phaseolus mungo* should be applied to *urd*.

Mung, also more commonly known as green gram, is a small herbaceous annual growing to a height of about 1 to 3 feet. The central stems are more or less erect. The side branches are sub-erect. The leaves are trifoliate, the leaflets being large, ovate and entire. Both the stems and leaves are covered with short hairs, but the hairs are generally not as long as those in *urd*. The flowers possess various shades of yellow colour, and are produced in a cluster. The pods are slender and about 2½ to 4 inches long. The seeds are small and nearly globular. The colour of the seeds is usually green, but yellow and brown seeds also occur. The hilum or scar in *mung* is not concave and is in that respect different from that of *urd* which possesses a concave hilum. Two types of root systems are found in the *mung* plants. The first, called the mesophytic type of root system possesses numerous laterals near the surface of the ground, whereas in the xerophytic type the lateral roots arise from the main root and extend obliquely downwards.

Mung is generally grown in this country as a *kharif* crop, but in some parts of the country, such as the Bombay Presidency, it is also

sown as a cold season crop. The soils on which it is cultivated are usually loams which are deep and well drained.

A classification of *mungs* or green grams in this country was made by Bose in 1932. He classified them into 40 different types mainly on the basis of the colour of seeds, flowers and pods.

Mung or green gram is usually sown mixed with other crops such as *jowar*, *bajra*, or cotton. It is believed to have the same restorative effect on the soil as the pigeon pea or gram. The seed bed preparation is similar to that for *jowar* and cotton. The seeds are usually sown broadcast, and the amount of seed when sown alone is about 8 to 10 lbs. per acre. As it is grown in the monsoon season, it is not an irrigated crop.

The crop is harvested before it is fully ripe as there is a danger of the shattering of the dry pods. The plants are cut by means of sickles and removed to the threshing floor and dried. The grains are then threshed by means of bullocks, and cleaned by winnowing from baskets.

The crop is fairly free from the attacks of fungous diseases and insect pests, but is sometimes susceptible to the attacks of leaf spot (*Cercospora cruenta*), rust (*Uromyces appendiculatus*), powdery mildew (*Erysiphe polygoni*), chlorosis (a physiological disease), the caterpiller of a moth (*Diacrisia obliqua*), and aphides

URD OR BLACK GRAM.

Urd or black gram is in all probability a native of India. It is today cultivated in many tropical and sub-tropical countries of the world. Thus it is now found in several regions in Africa, the southern countries of Europe, and in the tropical regions of the New World.

In India the crop is grown in most parts of the country and is one of the most highly valued pulses of India. The scientific naming of *urd* has been somewhat confused with that of *mung*, but most botanists now are agreed that the name *Phaseolus mungo* Linn. var. *Roxburghii* Prain should be given to *urd*, as this was first described by Linnaeus under the name of *mungo*.

The plant is a spreading annual with procumbent branches and is, to all appearances, very much like *mung* or green gram. The

stems and branches possess fairly long brown hairs, and it is, for that reason, known in some parts of the world as the "woolly pyrol". These hairs are usually longer than those in *mung* or green gram. The leaves are large, trifoliate and also hairy, generally with a purplish tinge. The colour of the leaves is green to dark green but usually lighter than that of *mung*. The leaflets are broad, ovate and entire. The inflorescence consists of a cluster of five to six flowers at the top of a long stout hairy peduncle. The corolla is pale or lemon yellow. The plants are almost universally self-fertilized, fertilization taking place even before the flowers open in a great many cases. The pods are about two or more inches in length, cylindrical and more or less curved, and are generally covered with fairly long hairs, longer than in *mung*. The seeds are oblong in shape and are either black or green, with a concave hilum which character distinguishes *urd* from *mung*.

The root system of *urd* is of two types, the shallow or mesophytic and the deep-rooted or the xerophytic type.

Phaseolus mungo or *urd* requires a fairly warm growing season, and is consequently grown in this country as a *kharif* crop; but in some parts it is also sown in February and harvested in May. The plant is believed to prefer a heavier soil than *mung*, but may sometimes be grown on light soils as is sometimes done in Bihar.

The black grams of India have been classified by Bose into two subspecies, one of which possesses large black seeds and hence named by him as *Niger*, and the other somewhat smaller and greenish seeds and hence named by him as *Viridis*. The black-seeded *urds* have been found to be early-maturing varieties, whereas the small green-seeded *urds* more commonly known as *urdi* (a diminutive of *urd*) are the late-maturing varieties. Then he further sub-divided *Niger* into 10 different types mainly on the basis of the colour of the seeds, the colour of the flowers and habit of growth of the plant. On the same basis, he sub-divided *Viridis* into fifteen different types. Thus the Indian *urds* have been classified by him into 25 different types.

The preparation of the land for sowing is similar to that for the *mung* crop. It consists of two or three ploughings at the commencement of the rains. Thorough preparation of the seed bed is not considered necessary, as this tends to encourage excessive vegetative

growth at the expense of seed development. The seeds are then sown broadcast at the beginning of the rains. Both the green and black varieties are sown at the same time. The black ones ripen in August and September, whereas the late-maturing green-seeded varieties ripen in October or November. When sown alone the seed rate for this crop is from 8 to 12lbs. per acre, but when sown as a mixed crop with millets, cotton, maize or any other crop, the seed rate is very much less.

Harvesting is done in the usual way as in the case of the *mung* crop.

The same diseases which attack the *mung* plants sometimes attack this crop also.

COWPEAS

The cowpea is probably a native of Central Africa, as throughout most of that continent wild plants resembling the cultivated cowpeas have been found, and these plants also cross readily with the cultivated ones. It is now grown in most parts of the world and is one of the most popular leguminous crops used in rotations in the United States of America. In India, while it is grown in most parts of the country, it is only produced on a very limited scale for use largely as a vegetable.

The term cowpea when loosely used include the asparagus or yard bean (*Vigna sesquipedalis*), the Indian cowpea (*V. catjang*), and the common cowpea (*V. sinensis*). The first species possesses pods 1 to 3 feet in length, while the pods of the second are only 3 to 5 inches long, and those of the common cowpea 8 to 12 inches long. Of these three the last is the most common.

The common cowpea is a vigorous herbaceous annual, more or less trailing in habit with stems 8 feet or more in length. The leaves are trifoliate with large cordate leaflets. The flowers are white or pale violet in colour. They are usually self-pollinated but the presence of extra floral nectaries encourages their visitation by insects and thereby cross-pollination. The pods are long and cylindrical and are somewhat constricted between the seeds. The seeds are numerous. They are bean-shaped and are variously spotted with different colours, the common colours being white, brown, green, yellow and mottled.

The root system of the cowpea consists of a well-developed tap root with a considerable number of laterals from the upper part. These spread out horizontally to about 1 to 2 feet. The greater part of the root system is located in the upper 18 inches of soil.

The cowpea requires a fairly warm growing season for its proper development. It may be grown on different types of soil, but will do best on well-drained loam soils.

No attempt has been made in this country to classify cowpeas. The characters which may be used for distinguishing the varieties now grown are (1) the habit of growth, that is whether erect, prostrate or bushy; (2) the length of the maturation period, that is, whether early or late; and (3) the character of the pods and seeds.

Some of the most successful varieties of cowpeas now grown in this country are the imported ones, such as "Black eye", "Whippoor-will" and "Groit".

The cowpea in this country is generally grown as *kharif* crop, but in some parts it may also be grown during the *rabi* season. The preparation of the land before sowing is similar to that for green and black gram. The crop is usually sown mixed with such crops as *jowar* and maize, but it may also be grown alone. When sown alone and in lines the amount of seed per acre is from 10 to 15 lbs. but when sown broadcast the seed rate is higher, 20 to 30 lbs. being considered sufficient for one acre. When sown thick, it usually does not require any weeding as the vigorous growth of the plants tends to smother out the weeds. It is for that reason sometimes used as a cover crop in order to suppress the growth of weeds.

If the crop is grown as a vegetable, the pods are picked while still green, and the stems and leaves may be fed either green or dry to cattle. If grown as a green-manuring crop, it should be ploughed under about the time the flowers begin to appear. If grown for seed, the plants are removed, dried and threshed as in the case of other pulses.

Certain diseases have been known to attack this crop. Among those occurring in this country are root rot (*Hypochnus solani*), rust (*Uromyces appendiculatus*), powdery mildew (*Erysiphe Polygoni*) and die-back (*Vermicularia Capsici*).

SOYBEANS

The soybean is undoubtedly a native of eastern Asia. A wild plant closely similar to the soybean, but more or less trailing in habit, has been found in some parts of China. The soybean is at present the most important oilseed crop of China and Japan. It is now cultivated in many other countries of the world such as Argentina, the United States of America, Australia and India, and its popularity in these new countries is growing very rapidly. In India the crop has been grown for a long time by the people of the hilly regions adjacent to the Himalayas, but its cultivation on the plains of India is being popularised as a fodder plant, as a soil renovating crop, and also as a pulse.

The soybean has had several scientific designations given to it but the name now adopted according to the international rules of botanical nomenclature is *Glycine max*. It is an erect or sub-erect herbaceous annual growing to a height varying from 1½ to 6 feet. The stems and branches are covered with short hairs. In appearance the plant is usually bushy. The leaves are trifoliate, the leaflets being fairly large. Some varieties shed their leaves before maturity, whereas others retain them up to the ripening period. The flowers are borne on short axillary recemes, and are either white or purple The flowers are generally self-pollinated, but cross-pollination may take place under field conditions. The pods are from 1 to 2½ inches long, each bearing two or more seeds. The pods are usually dark brown in colour and are always covered with short hairs. The seeds vary considerably in shape, size and colour. They may be yellow, green, brown or black. The root system consists of a tap root with a few laterals.

Soybeans may by grown under varying climatic conditions, and may in this respect be compared to cowpeas. They can also grow on all types of soils but prefer loams or clay loams for their proper development. The requirements of the different varieties differ greatly.

The preparation of the soil for the sowing of soybeans is also very similar to that for cowpeas. The seeds may either be sown in lines or broadcast. When sown in lines at a distance of about 2 feet apart it will require about 15 to 20 lbs. to the acre; but when broadcasted for either green-manuring or fodder purposes the amount of seed used per acre is about 30 to 40 lbs.

If grown for fodder the crop is cut when green and fed to cattle. When grown for green manure it is ploughed under when the plants begin to bloom. But when grown for seed purposes, the crop is harvested before the plants are completely dry as most varieties shatter very badly when left too long in the field. After cutting they are brought to a threshing floor and threshed in the same way as other pulses.

PEAS OR MATAR

The pea (*Pisum Spp.*) is probably indigenous to the region comprising Italy and south western Asia extending eastwards to the Himalayas, including northern India. Two main groups of peas are generally recognized: (1) the garden pea or *gol matar* (*Pisum sativum*), and (2) the field pea or *desi matar* (*Pisum arvense*). The latter is considered by some to be a sub-species of the former. *P. arvense* is also believed to be the older cultivated form, whereas *P. sativum* is of quite recent origin. The latter is usually grown in garden as vegetable but the field pea is commonly grown in this country as a field crop. The character which easily distinguishes them from each other is the colour of the flowers. For the garden pea has white flowers, whereas the field pea has coloured flowers. Only the latter is discussed here.

The field pea (*P. arvense*) is commonly grown as a field crop in the United Provinces, Bihar, the Central Provinces, Bombay, the Punjab, and Orissa.

The plant is semi-erect, but when a support is available it has a tendency to climb. The stems grow to a height of about two to three feet. It is much less vigorous than the garden pea. The leaves are pinnately compound, with one to three pairs of leaflets and one or more pairs of tendrils, The stipules are prominent and leaf like. The inflorescence is an axillary raceme. The flowers of the field pea are smaller than those of the garden pea, and are coloured, the colour of the standard being pale lilac, the wings purplish, and the keel yellowish white. Self-fertilization is common, but cross-fertilization may also occur. The seeds of the field pea are marbled and compressed, and are, in that respect, different from those of the garden peas which are large, globose and white.

The field pea is grown almost exclusively as a cold season crop in northern India. It is generally grown on heavy types of soil such

as loams and clay loams. The soil is prepared as in the case of gram and other *rabi* crops. It is sometimes sown mixed with *rabi* cereals such as wheat and barley. When sown alone, it is generally broadcasted at the rate of 60 to 80 lbs. per acre, and are then covered with soil by planking or harrowing. If sown in October, the crop is usually ready for harvesting about March or April. If the crop is grown for seed, harvesting begins when the seeds are mature. This is done by cutting the plants near the ground. They are then removed to the threshing floor where they are threshed out by bullocks

VETCHLING OR KHESARI

Khesari (Lathyrus Sativus) is indigenous to the region between the Caucasus and northern India. The crop has been under cultivation from very early times in countries such as India, Egypt, and Persia. In India, its cultivation is confined mostly to Bombay, the Central Provinces, Bihar, the eastern United Provinces and Sind.

The plant is an annual and is similar in appearance to the pea. The stems grow to a height of about 2 to 3 feet, but are more or less prostrate unless supports are available. The stems are quadrangular and also possess winged-margins. The leaves are pinnate with onl ya pair of narrow lanceolate leaflets and tendrils at the tip. The flowers are solitary, arranged in axillary racemes. The individual flowers possess long peduncles. The colour of the flowers varies in different types, being white, blue, red or pink. Self-fertilization of the flowers is the normal procedure, but cross-fertilization is also brought about by bees and other insects which visit them. The pods are four to five seeded, and may or may not possess red markings. The seeds are wedge-shaped and may be yellow, brown or variously speckled. It is generally believed that seeds of *khesari* cause a disease known as lathyrism, but recent work has shown that this disease is not caused by *khesari* but by seeds of a vetch known as *akta* (*Vicia sativa*), a weed, the seeds of which are very similar in appearance to *khesari* and are often mixed with it.

The crop is grown in this country during the cold season, and when the soil is too dry for other *rabi* seed crops. It also is commonly sown on heavier soils, although it does fairly well on the lighter soils also.

The Indian *khesaris* have been classified by Mrs. Howard and Rahman Khan into fifty-six different types. The main basis of the classification was the colour of the flowers, the presence or absence of markings on the pods, the size of the seeds and the colour of the seeds.

The preparation of the land for sowing consists in ploughing the land two or three times. The seeds are planted in lines about one foot spart at the rate of about 35 to 40 lbs. per acre. The seeds are then covered with soil by planking or harrowing. Before the plants are fully ripe they are cut and removed to the threshing floor and stacked for about a week until they are dry. When dry, they are threshed by bullocks in the usual way, and cleaned.

MOTH BEAN

The *moth* bean *(Phaseolus aconitifolius)* is probably indigenous to India, as wild plants occur all over the country, from Ceylon to the Himalayas. The bean is now grown in other parts of the world such as in China and the United States of America. In India it is mainly grown in the Bombay Presidency, the United Provinces, the Punjab and Rajputana.

The plant is a herbaceous creeping annual which spreads on the soil, forming a mat-like covering. This mat-like character has given it the name of mat-bean in the United States of America. The stems grow to a height of about a foot only with a spread of about two to three feet around the base. The branches are numerous and viny, the lower ones lying flat on the ground. The stems as well as the branches are covered with numerous hairs. The leaves are made up of three leaflets each leaflet being divided into 3 to 5 very narrow segments. The leaves are therefore similar in appearance to those of the aconite plant, a poisonous weed. Hence the plant has sometimes been called the aconite-leaved bean. The flowers are in a cluster with a long peduncle, making them appear above the leaves. But the individual flower pedicels are very short. Self-pollination is the common procedure, but cross-fertilization may occur under natural conditions.The fruit is a pod 1 to 2 inches long, and the seeds are more or less cylindrical with rounded ends.

The crop is usually grown during the *kharif* season and is very resistant to drought. Heavy rain is detrimental to it. It is grown on light and poor soils and is also commonly grown mixed with *bajra*.

The preparation of the soil for the sowing of this crop is very haphazard, and the seed is sown broadcast at the rate of about 10 lbs. per acre. If the crop is grown for fodder, it is cut when the pods have been formed; but if grown for seed, the crop is harvested when the pods are ripe. The crop is cut with sickles, removed to the threshing floor and threshed and cleaned in the usual way.

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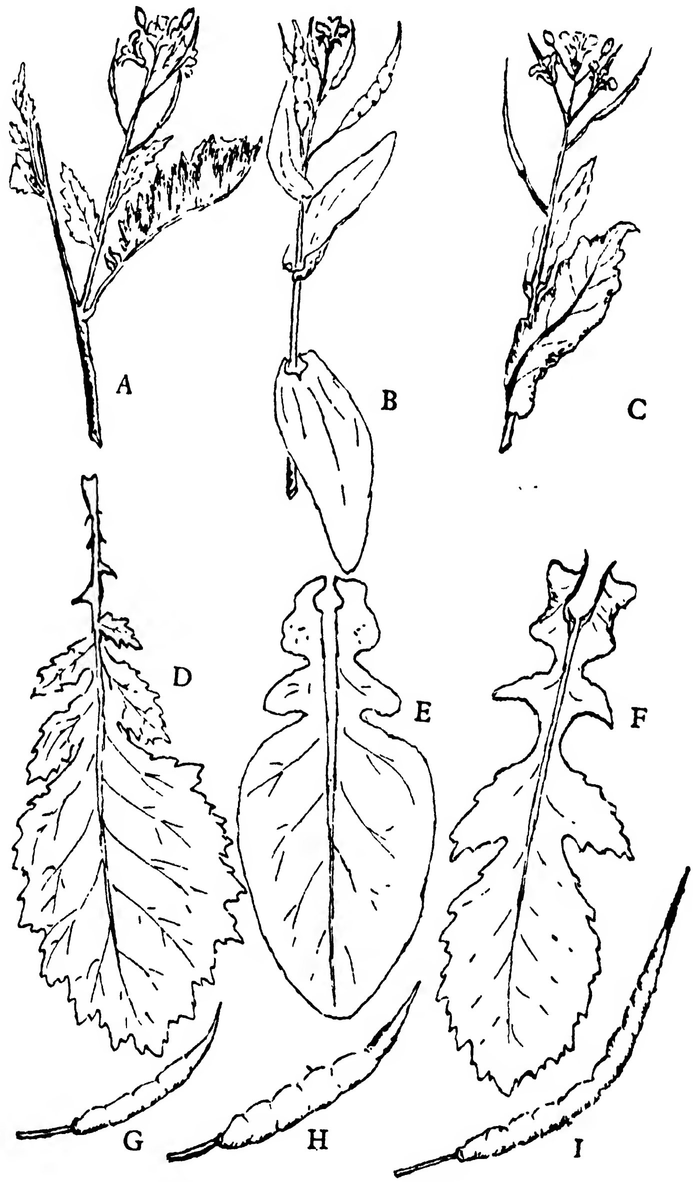
CHAPTER XXVIII.

MINOR OILSEEDS

In this chapter are included certain crops which are cultivated usually for the oil which is extracted from their seeds. These include the four mustard crops, namely *sarson*, *rai*, *toria* and *seoha*; and castor, safflower and niger.



A, A portion of the stem of rai; B, of tara-mira; C, of sarson. D, A leaf of rai; E, of tara-mira; and F, of sarson. G, a fruit of rai; H, of tara-mira; and I, of sarson. (Drawn by J. C. Borpuzari).

MUSTARD CROPS

Of the many mustard crops that are in cultivation in different parts of the world, *sarson*, *rai*, *toria*, and *seoha* are the most commonly cultivated in India. The first three are probably of European origin, whereas the last is believed to have originated in Africa. These mustards are cultivated in many parts of India, but are

more extensively grown in the northern parts of the country than in the south.

Rai (*Brassica juncea*) is probably the most common of all the cultivated mustards of India. The plant is a tall, erect, herbaceous annual, 3 to 5 feet in height, and much branched. The leaves are not dilated at the base and not clasping, as in the case of the other mustards, but are stalked and pinnatifid. The inflorescence is a terminal raceme. The fruits are slender and only 1 to 2 inches long, with a beak about $\frac{1}{3}$ the length of the pod. The seeds are small, and dark or reddish brown in colour.

Sarson (*Brassica campestris* L. var. *Sarson*) is also commonly cultivated in this country. The plant is usually shorter than *rai*. It is easily distinguished from the latter by the character of the leaves, which in *sarson* partially clasp the stem. The fruits also are thicker than those of *rai*, and are laterally compressed, with a beak $\frac{1}{3}$ to $\frac{1}{2}$ their length. The seeds are either yellow or reddish brown The seed coat is smooth which also distinguishes it from *rai*, the seeds of which possess rough seed-coats.

Toria or *rape* (*Brassica napus* var. *dichotoma*) is the mustard more commonly cultivated in the Punjab. The plant is more vigorous and more hardy than *rai* or *sarson*. It grows to a height of 4 to 6 feet. The leaves are more or less clasping, pinnatifid and lanceolate.

The following key (adapted from Duthie and Fuller) may be used in the identification of the above three mustards.

A. Leaves usually hispid, stalked or the upper ones sessile, not auricled and therefore not clasping the stem; fruits slender, more or less constricted. Seeds small, dark brown or reddish brown, distinctly reticulated...... .... *Brassica juncea (rai).*

AA. Leaves usually glaucous (*i.e.* not hispid), auricled and more or less clasping the stem ; seeds yellow or brown.

B. Racemes few flowered ; sepals erect ; fruits thick, not constricted ; seeds large..............*Brassica campastris*, var. *sarson (Sarson).*

BB. Racemes many-flowered ; sepals spreading ; thickness of fruits intermediate, somewhat constricted ; seeds brown or reddish brown, rather large, with minute wrinkles..........*Brassica napus*, var. *dichotoma (Toria).*

Seoha or *tara-mira* (*Eruca sativa*) is a more or less herbaceous annual, about 2 or 4 feet high. The stems are solid and are covered

with stiff hairs. The leaves are stalked and are from 6 to 12 inches long. The inflorescence is a raceme. The petals are distinctly clawed. The flowers are extensively cross-pollinated; and it is believed that they are self-sterile. The seeds or ovules are in a double row or series in each compartment of the fruit, a character which distinguishes it from the brassicas, in which the seeds or ovules are in a single row or series in each compartment of the fruit. The fruits are also shorter and rather stoutish.

The oil content of the seeds of these various mustards is somewhat as follows:—

Rai (*Brassica juncea*)	21 to 28 per cent.
Sarson (*Brassica campestris* var. *sarson*)	33 ,, ,,
Toria (*Brassica napus* var. *dichotoma*)	33 ,, ,,
Seoha (*Eruca sativa*)	12 to 25 ,, ,,

These mustards are cool-season crops and are therefore grown in the *rabi* season. They are grown on a very large variety of soils.

The mustards are usually sown mixed with other crops such as wheat, gram or barley, but in some cases they may be sown alone as in the case of *toria* in the Punjab. Sometimes *sarson* is also sown in small plots for use as a vegetable (pot-herb). The preparation of the land for the sowing of mustard crops is generally that for the crop with which it is associated.

Sometimes these mustards are cut green and fed to cattle. But when grown for seed, the plants are cut by hand with a sickle, when mature. They are then dried and threshed.

The mustard crops are subject to the attack of certain fungous diseases, such as white rust (*Cystopus candidus*), downy mildew (*Peronespora parasitica*), and blight (*Alternaria Brassicae*). White rust has been found to occur in *seoha* or *tara-mira* and a few other related plants. The disease appears as a white crustation on the leaves and may cause the thickening and swelling of the stems as well as of the floral organs. Downy mildew has been found to occur in all these mustards and also on some other related plants. This also causes an abnormal deformity of the stems but usually not of the flowers. The disease more commonly appears on the under surface of the leaf as whitish spots. Blight attacks all the green parts of the plants, but

more especially the fruit. The disease appears as small brown or blackish spots which first form on the leaves but later spread to the fruit.

The worst enemies of the mustard crops are the aphides, especially on the late crop. These small greenish and soft-bodied insects suck out the juice from all parts of the plant and thus sometimes almost completely destroy the crop. These insects are known to be controlled in nature by other insects such as the lady-bird beetles. They may, however, be controlled to some extent by sowing the crop early, as the second or third brood may be produced in the early crop, which may attack the crop sown later.

CASTOR

The castor plant (*Ricinus communis*), a member of the *Euphorbiaceae* family, is probably a native of Africa. It is now grown throughout all tropical and sub-tropical countries. In India, it is grown almost all over the country, the cultivation of the crop being not confined to the plains but also grown at higher elevations. The following table will show its distribution in India according to provinces and states.

TABLE XXXXI

Showing the distribution of castor in India

Provinces and States.	Area in acres in		Production in tons of seed in	
	1933-34	1937-38	1933-34	1937-38
Hyderabad	825,000	520,000	67,000	40,000
Madras	305,000	247,000	31,000	22,000
Bombay (including States) ..	108,000	89,000	15,000	13,000
Bihar and Orissa	56,000	{ 34,000 20,000	9,000	{ 5,000 2,000
Central Provinces and Berar ..	37,000	32,000	7,000	6,000
Mysore	106,000	96,000	6,000	5,000
Baroda	81,000	88,000	5,000	7,000
United Provinces	8,000	13,000	2,000	4,000
Sindh	8,000	7,000	1,000	400
Total ..	1,534,000	1,146,000	143,000	107,000

The castor plant is a shrub or small tree growing to a height of about 10 to 15 feet. Its branching habit is somewhat different in different varieties. The stems and branches are glaucous and either red or green or with shades of both, and are hollow. The leaves are petioled (occasionally they are sessile near the base), alternate, peltate and green with a red tinge. The young leaves are, however, more reddish in colour. There are usually 8 to 10 lobes on a leaf. The lobes are usually fairly broad, but laciniate ones as well as intermediates also occur. The inflorescence consists of a raceme made up of unisexual flowers, the females occuring at the top and the males at the bottom. The flowers are wind-pollinated. In order to prevent cross-pollination between varieties, it is desirable to plant them at a distance at least 40 yards apart. The fruit is a capsule made up of several compartments. Two sizes of seeds are generally recognized, large and small. The quantity of oil in the best varieties is from 54 to 56 per cent in the whole (unhulled) dry seed. The amount of oil in the seed depends more on the degree of maturity than on any other factor. It has also been found that the oil content is higher in a warmer climate.

The castor plant in warmer regions is a perennial, but at higher altitudes and in colder regions it is an annual. It is grown in most types of soil, but thrives best in loams. The plant is also considered to be very tolerant of drought, but does not tolerate standing water, and is very susceptible to frost.

No attempt has been made to classify this crop in detail, but it is generally known that it contains at least two different groups, the small-seeded and the large-seeded. The former are early-maturing whereas the latter are late-maturing. Some investigators are of opinion that the small-seeded varieties contain a higher oil content than the large-seeded ones. It is also the general opinion that the small-seeded varieties possess oil of higher quality which is used for medicinal purposes, whereas the high-seeded types yield the best ordinary lubricating lighting oils.

The crop is usually cultivated on the edges of fields, but occasionally it is sown mixed with such crops as the pigeon pea and *sem* (*Dolichos lablab*). It is very seldom grown alone. The method of preparation of the seed bed is the same as that for the crop with which it is associated. In northern India the crop is generally sown

in the beginning of the rains, but in other parts of the country it may be sown as a *rabi* crop. When sown as a *kharif* crop in northern India, the land is ploughed two or three times at the beginning of the rains, and the seeds are sown in rows about 4 to 6 feet apart either by dibbling or by dropping behind the plough. The plants are then thinned by removing the weakest ones. This may have to be done more than once, until the plants are left 3 to 4 feet apart. The crop may require watering if the rains are insufficient, and one or two weedings during the whole period of growth. The crop takes about 10 months to reach maturity.

The harvesting of the crop consists in picking the mature capsules (fruits) by hand. The picking may continue for one or two months. In some varieties the capsules dehisce (open) and in some they are indehiscent. The indehiscent types are collected and stacked and covered with a cloth or straw. After a few days the capsules are exposed to the sun and on drying the shells split open. If they do not open they are beaten with a wooden mallet until the seed separates from the shell. The seeds are then dried and stored until ready for sale. From the seeds the oil is extracted which is used extensively for medicinal purposes and as an illuminant. More recently the demand for the oil has extended, for use in internal combustion engines and the lubrication of aeroplanes and airships.

The leaves of this plant are sometimes used for rearing *eri* silkworms from which the *endi* or Assam silk is manufactured.

The castor plant is subject to the attack of several fungous diseases and insect pests. The most common of the fungous diseases in this country, is known as the seedling blight (*Phytophthora parasitica* Dastur). This disease, while it commonly occurs in the seedling stage, also attacks the leaves of older plants. The disease in the early stages attacks the young cotyledons and later spreads to the stalk causing the leaf to droop and rot. In the older plants the attack is more localised, being restricted to the leaf. The leaf spots are yellow and later turn brown.

Another fungous disease which attacks the crop; is known as rust caused by the fungus *Melampsorella Ricini*. This disease has been found to occur in the Bombay Presidency and in the Central Provinces. Still another fungous disease which attacks this

crop is known as leaf spot (*Cercosporina ricinella*). This appears as spots on the leaves, the centre of the spot being pale brown, which changes to greyish white and is surrounded by a deep brown band.

A new disease has been reported from the United Provinces, caused by *Botrytis* sp. This disease attacks the plants and destroys the fruiting racemes at the early stages of growth.

The castor plant is also attacked by a number of insect pests, the most common of which are a stem-borer and seed-eating caterpillar (*Dichorocis punctiferalis*), a mealy bug which sucks the sap out of the leaves and which is known as *Aleurodes ricini*, the smooth caterpillar (*Ophiusa melicerti*), the hairy caterpillar (*Trabala rishnu*), and the spiny castor caterpillar (*Ergolis merione*) the last three being leaf-eating caterpillars.

SAFFLOWER

Safflower or *kusum*, according to De Candolle, is probably a native of Arabia. More recently Russian investigators expressed the opinion that perhaps the cultivated forms of safflower had originated in two centres. One centre is Abyssinia from which it spread into Egypt, and another centre is in Afghanistan whence it spread into India and the neighbouring countries. But the Egyptian types are more or less uniform, the Indian types are very variable, due probably to the wide climatic differences which prevail in this country.

Its cultivation today is mainly in Egypt, southwest Asia, some of the Mediterranean countries, and India. In this country it has been cultivated from very early times, and is grown in almost all the provinces. But the acreage devoted to this crop in this country is declining, probably due to the competition of the chemical industries.

Safflower (*Carthamus tinctorius*) varies greatly in height, the dwarfy types being about one and a half feet tall, and the taller forms being about 2 1/2 to 3 feet. The plant is glabrous, thistle-like, and much-branched near the top. The leaves are sessile, oblong and lanceolate, but differ in different varieties in the degree of sharpness of the apex, the serration of the margin and the number and size of the spines. The inflorescence is a capitulum or head more or less typical of the sunflower family (*Compositae*) to which it belongs. The inflores-

cence is subtended with the involucral bracts which may be spinose or entire. The character of the involucre is believed to be different in the oil-yielding and the dye-yielding forms. The spinose bracts are believed to be associated with the oil-yielding forms, whereas the dye-yielding forms are mostly entire. The colour of the flowers varies from light yellow to orange or red. Yellow colour is usually associated with the oil-yielding forms, and the orange or reddish colour is associated with the dye-yielding forms, these colours probably showing the presence of carthamine. The flowers may be self-or cross-pollinated under natural conditions; selfing, however is believed to be more common than crossing. The seed varies in size, depending on the influence of the environment and the position of the seed on the capitulum. The percentage of fat in the seeds varies with the different varieties, from 20 to 30 per cent.

Safflower is considered to be a drought-resistant crop, and is therefore grown in this country in poor sandy soils, usually as a border crop for barley, gram, tobacco, wheat, etc. The plant, however, does better in rich loams which are retentive of moisture.

An attempt to classify the Indian safflowers was first made by Howard and his colleagues in 1915 More recently (1935). Sabnis and Phatak have revised the previous classification and have added 29 new types bringing up the total of Indian types to 63. Their classification is based mainly on the character of the bracts, that is, whether spinose or spineless; the shape of the outer bracts; the character and colour of the inner bracts; the colour of the florets and growth habit of the plants.

The Russian worker, Kupzow, in 1932, attempted to classify the safflowers collected from different parts of the world. In his classification, he divided the safflowers into 21 different ecotypes which together make up two different groups, the eastern and the western. A reference to this work is given at the end of this chapter.

Safflower is sown in this country with *rabi* crops, in most cases on the edges of fields to protect the crops from predaceous animals. When sown alone the seeds are either broadcasted or drilled. The amount of seed per acre when sown alone is about 16 lbs. When the plants have developed a central flowering head, the tip is nipped, as this is believed to encourage the dvelopment of lateral shoots and consequently increase flowering.

When the crop is grown for dye, the petals are collected every two or three days when the bright colour is fully developed. Any delay in collecting will result in the loss of dye. Rain during the flowering period is also very harmful as it washes the colouring matter out of the flowers. The immature seeds are left on the plant and allowed to ripen, thus producing a supplementary crop.

When the crop is grown for oil, the petals may or may not be collected, and when the seeds are ripe, the plants are cut, and the seeds are threshed in the usual way. From the seeds, the oil is extracted which is used for cooking as well as for adulterating ghee.

A leaf-spot disease of safflower caused by *Cercospora carthami*, Nov. Sp. has been reported to occur on the Coimbatore Central Farm, but is not known to occur anywhere else in India.

NIGER OR RAMTIL

Niger or *ramtil* (*Guizotia abyssinica*) is probably a native of Africa, but is grown in some parts of India, especially in the Bombay Deccan and the Madras Presidency as an oil-seed crop. It is also grown here and there in the provinces of Bihar, Orissa, and the States of Mysore and Hyderabad.

The plant is a member of the sunflower family or *Compositae*. It is an erect harbaceous annual, about 3 to 5 feet high, and much branched, most of the branches extending almost to the top of the plant. The leaves are sessile, partially clasping the stem, the shape of the leaf being ovate-lanceolate. The inflorescence is a capitulum or "head" typical of the *Compositae* family and about ½ to 1 inch in diameter. The colour of the flowers is yellow. The mature seeds are small and black in colour, the number of seeds in each head being about 20 or more.

Niger is a sun-loving plant and requires a good deal of warmth for its proper development. It prefers light sandy soil, but requires moisture during its period of growth. In this country it is usually grown during the *kharif* season.

No attempt has been made to classify this crop, but general field observations would indicate that the nigers grown in this country may

be classified into "early" and "late," according to the length of their growing season.

The preparation of the land for the sowing of the seed is very simple, consisting of one or two ploughings followed by planking. The seeds are usually sown broadcast at the rate of about 10 lbs per acre. When sown in lines the seed rate is usually less, being about 5 lbs. per acre, the distance between rows being about 14 inches. The crop usually takes about three to four months to reach maturity.

When the crop is ripe, the plants are cut near the root and stacked for about a week. The crop is then spread out and dried in the sun for two or three days and when quite dry the seeds are threshed, and separated from the other materials, by winnowing. The oil extracted from the seeds is used for cooking purposes and for adulterating more valuable oils.

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CHAPTER XXIX

FODDER CROPS

The subject of fodder crops is growing very rapidly in importance during recent years. The reasons for this are several. One of the reasons is the development of the dairy industry in the country, demanding that more attention be given to the question of better fodder crops. Another reason which may account for the growing importance of fodder crops in this country is the reduction in the pasture lands available for general grazing. Also, the general improvement in agriculture, such as the evolution of better varieties of crops, the use of better implements, and in short, the general improvement in cultural methods, demands more and better animal power. Lastly, an increasing knowledge of what constitutes good nutrition both for human beings and for animals, which has led to an increasing use of milk by the former and the use of more palatable and nutritious food for the latter, is also responsible to some extent, for the interest in and search for more nutritive fodders. For these and other reasons, the subject of fodder crops is one of enormous agricultural importance in this country.

Most of the fodder crops fall into two more or less natural groups: (1) the grasses and (2) the legumes. The following are some of the most important fodder grasses grown in this country: (1) Napier or elephant grass, (2) Guinea grass, (3) oats, and (4) *dub* or *hariali* grass, etc. Among the legumes commonly used for fodder purposes, the following are important: (1) lucerne, (2) clovers, and (3) *guara*.

FODDER GRASSES

Napier or elephant grass (*Pennisetum purpureum* Schum).—This plant is indigenous to central Africa where it is found growing extensively in the high grass savannas of that region. According to Bews and Phillips, the elephant and Napier grasses are two closely related varieties of *Pennisetum purpureum*, but differ in minor characters. The plant seems to have been used extensively as a fodder for the first time in Rhodesia. It was probably introduced into this country about the year 1915. Since then it has spread rapidly to different parts

of India and is being grown mostly in Government experimental and demonstration, and private dairy farms.

Napier or elephant grass is a tall perennial grass growing to a height of about 6 to 10 feet. The plant tillers profusely, the number of tillers at the end of the first year being about twenty, and the clump increases in number of tillers as well as in size year after year. The tillers are somewhat obliquely erect. The lower part of the stem is usually smooth, but the portion of the stem near the top is usually hairy and is covered with a bloom. The leaves are typical of the grasses. The leaf-sheath clasps the stem and is generally smooth, but may sometimes be somewhat hairy. The leaf-blade is linear and is about two to three feet long. The inflorescence is a dense spike about 6 to 12 inches long. The seeds are not known to develop to maturity.

As no mature seeds are produced, the plant is always propagated vegetatively. Rhizomes, cuttings and rooted slips are all used for the propagation of this crop. But rooted slips are known to give the best and quickest results. The slips are planted in lines three to four feet apart and at a distance of two to three feet apart in the lines. The crop is ready for the first cutting in about four months, and successive cuttings after that at intervals of about a month depending on the water supply and season of the year. The crop responds very readily to irrigation but can stand drought fairly well. It is, however, very susceptible to frost. The crop does best under irrigation. Under such conditions it will easily yield about 200 maunds per acre in one cutting. Hence the average yield of green fodder in a year with an average of about 10 cuttings is about 2000 maunds. However yields as much as 4000 to 5000 maunds per acre have been reported. The grass is usually fed green to cattle immediately after cutting, but it is known to make a fairly good silage.

Guinea grass (*Panicum maximum* or *P. jumentorum*).—This grass is indigenous to Africa, whence it was introduced to Jamaica and other parts of the world. From Jamaica it was introduced into India about the end of the eighteenth century. Since then it has been recommended as a fodder grass for most parts of India.

The grass is a perennial growing to a height of about 4 to 6 feet or more, especially if it is allowed to grow until the inflorescence has developed on the apex of the plant. The plant, like Napier grass,

tillers freely, producing from twenty to thirty tillers in the course of one year. The tillers are more or less erect, but the outer ones are more oblique, especially near the base. The stalks are not so thick as in the Napier grass but are usually larger than a lead pencil. The leaves are not so broad as those of Napier grass. They are also coarser in texture. However, there is a considerable variation in the width of the leaves of this grass in the different ecotypes, that is strains or varieties coming from different geographical regions, some ecotypes possessing leaves as broad as those of maize. The inflorescence is a loose panicle, the longer branches being those towards the bottom of the inflorescence. The seeds are readily shattered so that it is difficult to obtain mature seeds. Some, however, may be collected if the panicle is removed before the seeds are mature, and cured in the shade.

The plant grows well in the warm tropical climate of this country. Although the plant is fairly drought-resistant, it will do best in places where a fairly large amount of moisture is available in the soil. The crop, however, will not do well in water-logged areas. During the low temperatures which prevail in northern India during the winter, the plant stops growing and lies dormant, but with the approach of the warm weather it again grows rapidly if sufficient moisture is available. It is also easily damaged by frost. While it may be grown in almost all types of soil, it will do best in light to medium loams.

The crop may be propagated by seed but is more commonly grown from root-slips or setts. These are usually planted in lines about three feet apart and about 2 feet apart in the lines. The root-slips or setts are planted on the edges of large ridges. Irrigation water is allowed to flow in the furrows between the ridges. In most parts of India, irrigation water is necessary if the crop is to be grown economically and commercially.

The crop once planted will last for several years. It is, however, advisable to break up the clumps after three or four years and to replant the setts after heavily manuring the soil. It would, however, be more advantageous to plant the crop on new land if available.

The crop is generally cut while it is quite green and tender before the stems get coarse and tough. The oftener the crop is cut the finer and better will be the fodder. The number of cuttings obtain-

able in one year varies from 8 to 10, and the yield of green fodder per cutting is about 150 to 175 maunds per acre. Therefore the yield of green fodder per acre per year may vary from 1200 maunds to 1750 maunds.

Oats (*Avena* sp.).—The primary centre of cultivated oats, according to Malzew, a Russian investigator, is probably the western Mediterenean region, that is the region round Mount Atlas in Africa, and the country round the Pyrenees. All the wild and cultivated oats of the world fall into three groups according to the number of chromosomes, the diploids with 14 chromosomes, the tetraploids with 28 and the hexaploids with 42. *Avena sterilis*, according to Malzew, is one with 42 chromosomes. *A. sativa* also possesses 42 chromosomes but is believed to have originated independently from the wild oat *A. fatua*, and not from *A. sterilis*.

Investigations made by Bose at Pusa seem to show that the Indian oat is *Avena byzantina* of the group *A. sterilis* and is not the common cultivated oat, *A. sativa*. *A. sterilis*, has its secondary origin, according to Malzew, in the Pamirs.

Oats have now become a crop of some importance in several parts of northern India, as a fodder crop, especially on the Government military farms. But it is occasionally grown as a grain crop in some parts of the Punjab and the United Provinces adjacent to Delhi.

The oat is an annual plant and is very similar to wheat and barley. But the stems are usually larger and softer than those of wheat and barley. The plant also usually tillers more freely than either wheat or barley and is therefore somewhat bunch-like in appearance. The leaves are also broader and more abundant than in wheat or barley. In oats the auricles are absent, a character which distinguishes it from wheat and barley.

The inflorescence, unlike that of wheat and barley, is a loose panicle. The branching of the inflorescence decreases from the base of the panicle upwards and usually spreads in all directions. These branches, however, may be upright or drooping, and in some varieties may appear to turn in one direction only. The flowers are, as a rule, self-pollinated, but cross-fertilization sometimes takes place under natural conditions. The root system of oats is very similar to that of wheat.

The mass of the roots are confined to the first two feet of soil, but certain roots may penetrate to a depth of about 4 feet.

Oats is a cool season crop and its growth in this country is confined largely to the plains of northern India. It does best on heavy soils such as loams and clay loams.

The method of growing this crop is very similar to that of the small grain cereals such as wheat or barley.

Two varieties of oats evolved at Pusa, known as B. S. 1 and B. S. 2 are considered to be high yielding and also resistant to drought and diseases.

Dub or hariali grass (*Cynodon dactylon*).—This plant has been dealt with in a previous chapter under weeds. But while it is a serious weed in some places, it is also the best known of all the fodder grasses in India, as it grows in all parts of the country and is fed to cattle as well as to horses and other animals The grass is indigenous to this country. It is also used extensively as a pasture grass and for lawns. The grass has been introduced into America under the name of Bermuda grass. The grass is propagated chiefly by seed and by rooted cuttings. This is most successfully done during the rainy season The crop will grow in most types of soil but does not do well on poor soils or on water-logged areas. The crop also does not do well under shade.

Sudan grass (*Andropogon sorghum* var. *sudanensis*).—This plant is related to *jowar* but is grown only for fodder purposes. The grass is also closely related to Johnson grass (*Sorghum halepense*) which is usually a weed, as it developes rhizomes by which it spreads very rapidly and is thereby difficult to eradicate. Sudan grass is becoming popular in northern India, where it is usually grown under irrigation. Under these conditions three or four cuttings may be obtained in one year. The grass yields about 200 maunds of green fodder per cutting or 600 to 800 maunds per annum.

Teosinte or buffalo grass (*Euchlaena mexicana*).—This grass is a native of Mexico, and is closely related to maize with which it forms hybrids. The plant is also similar in appearance to maize and grows to a height of about 8 to 12 feet. The plant, however, tillers more freely than maize, and is therefore given more spacing than

maize in order to give it a chance to produce abundant tillers. It is grown in this country as a *kharif* crop, and it does fairly well under humid conditions. The crop is cut several times in one season, yielding about 200 to 250 maunds of very palatable fodder in one season.

Besides the fodder grasses mentioned above, other grasses such as *jowar*, maize, and *bajra* are extensively used in this country for fodder purposes. These crops have been dealt with previously in separate chapters.

FODDER LEGUMES

Lucerne or alfalfa (*Medicago sativa*).—This is one of the most important leguminous fodder crops of the world. Its origin is probably southwestern Asia, that is, Turkey, Persia, and Afghanistan. It was probably the earliest crop grown by the peoples of Asia exclusively for fodder purposes. Its cultivation to-day is quite extensive in the drier regions of the world.

The plant is a herbaceous perennial, growing to a height of about two to three feet. The branches arise from a short compact stem at a point a little above the ground level known as the "crown". The number of branches may be as many as forty. The leaves are trifoliate, the middle leaflet possessing a short petiole, a character which distinguishes it from a clover leaf. The plant possesses a tap root which penetrates very deeply into the soil, with but few lateral roots. The colour of the flowers is usually purple but sometimes it may be blue, green, or yellow. The flowers, under natural conditions, are both self-and cross-pollinated. The fruit is an indehiscent pod coiled two or three times. The seeds possess a very hard seed-coat and therefore they retain their viability for several years. New lucerne seeds do not germinate as satisfactorily as those two or three years old. New lucerne seeds, if scarified, germinate well, the inhibiting cause being believed to be the hard and impermeable seed-coat.

Lucerne can stand a wide range of temperatures. The high temperatures prevailing in northern India do not seem to damage the crop. The plant can also withstand fairly low temperatures, the degree of resistance being of course different with different varieties. If the high temperatures are, however, accompanied with high humidity, the

plant usually will suffer. It cannot, therefore, be grown satisfactoi as a perennial crop where the amount of rainfall is beyond 40 inches annually.

Lucerne can also grow well on most types of soil, but it does best on a deep well-drained loamy soil. It does not do well on soils which are subject to water-logging.

The crop is either sown broadcast or in lines, on ridges. The former practice is usually followed in the semi-arid regions of the country, whereas the latter is the more common practice in regions of high rainfall. The seeds are usually sown in most parts of northern India during the months of September and October. The amount of seed used per acre is about five seers. Immediately after sowing the first irrigation is given, and the seed bed is always kept moist by further irrigations until the seedlings are above the ground. After this, irrigations are given at intervals of about 15 to 20 days during the hot season and at longer intervals during the cold season.

The crop is frequently infested with a number of weeds such as *dub* and *motha* in the hot season and *bathua* in the cold season. These should be carefully removed.

The number of cuttings depends upon the length of the growing season and the amount of water given to the crop during the year. The first cutting is usually taken when the crop is about two to three months old. This is done more especially with the object of getting the plants to develope more branches from the crown. The subsequent cuttings are made when the crop is about $\frac{1}{4}$ to $\frac{1}{3}$ in bloom. This is believed to be the period when the leaves are richest in nutritive substances. The number of cuttings obtained in one year is about 6 to 8, and the yield of green fodder per acre per annum is about 600 to 800 maunds. The crop once planted will last for several years. It is, however, not advisable to leave it for more than 4 to 5 years.

Clovers.—The most common of the clovers now cultivated for fodder purposes in this country are *berseem* (*Trifolium alexandrinum*), also sometimes known as Egyptian clover, *shaftal* (*Trifolium resupinatum*), also known as Persian clover, and *senji* or Indian clover (*Melilotus parviflora*). Besides these three, burr clover (*Medicago hispida* var., *denticulata*), which commonly occurs in North India as

weed, in wheat fields, and fenugreek (*Trigonella foenumgroecum*), more commonly known in India as *metha* and *methi*, are related plants of the clovers and are, like them, used in certain parts of India as fodder plants.

The following key may be used in order to identify the cultivated clovers and related fodder plants found in this country.

A. Leaves palmately trifoliate, flowers in a compact head ....*Trifolium.*

B. Seeds reddish ....*T. alexandrinum.*

BB. Seeds brownish and smaller ....*T. resupinatum.*

AA. Leaves pinnately trifoliate, terminal leaflet stalked.

B. Pods spiral; flowers in head or short spike ....*Medicago.*

C. Pods toothed.......................................*M. Hispida.*

CC. Pods not toothed.................................*M. Sativa.*

BB. Pods straight.

C. Pods beaked, several inches long.....................*Trigonella.*

CC. Pods not beaked, short.............................*Melilotus.*

Berseem or Egyptian clover was introduced into India from Egypt probably in 1904. Since then the crop has considerably increased in importance not only as a fodder, but also for the renovation of the soil. This is a herbaceous annual growing to a height of about 1½ to 2 feet or more. It usually possesses white flowers. Two varieties are generally cultivated in India—*Miscawi* and *Khadrawi.*

Shaftal or Persian clover is indigenous to Central Asia whence it was introduced into this country. This plant resembles *berseem* in habit and appearance, but it is not as vigorous and has a tendency to lodge. The stems are hollow and do not grow as tall as *berseem.*

Senji or Indian clover, (also sometimes known as bitter clover) is commonly grown in the Punjab and in the Northwestern districts of the United Provinces. The plant grows to a height of about 1½ feet. This fodder should not be fed alone in large quantities but should be mixed with *bhusa*, or other dry matter, lest it cause tympanitis.

Burr clover is a semi-erect, almost creeping annual. The leaflets often possess white or reddish spots, which disappear with age. This crop is not grown as a cultivated crop in India, although the plant is found growing wild in the United Provinces, the Punjab and other parts of northern India.

Fenugreek is usually an erect plant with several branches. Two fairly distinct varieties are generally recognised. The tall-growing variety known as *metha* is commonly used as a fodder for cattle, and the dwarf variety known as *methi* is generally used as a condiment or pot-herb. The seeds possess medicinal properties.

All the clovers are usually sown during the cold season, usually in October. The land is prepared as for ordinary *rabi* crops and irrigated, and the seed broadcast. Sometimes the seeds are steeped for 24 hours before sowing. The amount of seed used per acre in the case of *berseem* is about 30 to 40 lbs. but for *shaftal* and for *senji* it is only about 20 lbs. In the Punjab, *senji* seeds are often broadcast in the growing crop of cotton or maize, just prior to the last irrigation given to those crops. In this way, the labour and expense in the preparation of the seed bed is saved. All the clovers are grown as irrigated crops. Two or more cuttings can be obtained from *berseem* and *shaftal* in one season, most of the cuttings being taken from December to April.

Guara (*Cyamopsis psoralioides*).—This plant is grown mainly as a fodder crop but also for green-manuring purposes in several parts of northern India. The plant is probably indigenous to this country. It is a herbaceous and erect annual. The stems are simple with relatively few branches. It usually grows to a height of about 3 to 6 feet, but certain varieties have been reported to grow as tall as eight to ten feet. The leaves are trifoliate. The flowers are borne in short axillary racemes. The pods are somewhat flattened and are 1½ to 2 inches long, each pod bearing about seven seeds. The pods are somewhat erect and are borne in a cluster, hence the plant is also known as the cluster bean. When the pods are tender, they are often used as vegetables. Two varieties of this plant are geenerally recognised, the giant and the dwarf. The giant variety commonly grown in Gujarat is tall and possesses larger pods and seeds than the common or dwarf variety which is more commonly grown in the Punjab and the United Provinces.

This legume is generally grown as a *kharif* crop in northern India. It does best on sandy loams and does not do well in the black cotton soil. The seeds are usually broadcast and then covered either with a harrow or a planker, but sometimes they are also sown in lines,

In the Punjab, the crop is usually sown alone ; but in the United Provinces it is usually mixed with *jowar*. When sown alone the amount of seed used is about 10 lbs. per acre. When the crop is grown for fodder, the plants are cut when in flower or when the pods are beginning to form. When grown for seeds the crop is left until the plants are mature.

Kulthi (*Dolichos biflorus*).—This crop is grown extensively in the Bombay and Madras Presidencies, and to some extent in the hilly regions of the United Provinces, and in Chota Nagpur, the northern districts of Bengal and also in some parts of Assam, and is, like *guara*, grown for both fodder and for green-manuring purposes This plant is indigenous to this country. The plant is a much branched annual, the branches intertwining among themselves or with the plants with which the crop is grown. The leaves are trifoliate, the leaflets being ovate and entire. The flowers are borne one to three together in the axils of the leaves. The pods are 1½ to 2 inches long, flat, much recurved and tipped with a persistent style. They contain from five to six, usually variegated, seeds.

The crop does best on light sandy soil, and is extensively grown on the light red stony soils of the Deccan. The preparation of the soil is similar to that for other pulses. The crop, in most parts of the Deccan, can be grown at almost any time of the year, but in northern India it may be grown either as a catch crop after the *rabi* harvest or as a *kharif* crop When grown for fodder, the seeds are sown more thickly at the rate of about 25 lbs. per acre. When grown for fodder the crop may be harvested about a month and a half after sowing.

Minor leguminous fodders.—Besides those mentioned above, there are a number of leguminous plants which are more or less used for fodder purposes Such are soybeans, peas, Japanese clover (*Lespedeza striata*), groundnut tops, cowpeas, *sem* or hyacinth beans (*Dolichos lablab*), *urd*, *mung*, *moth*, *khesari* and the vetches.

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